JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 34 June, 1941 No. 3

The Place and Methods of Breeding for Insect Resistance in Cultivated Plants.[1]

RALPH O. SNELLING,[2] *Urbana, Illinois*

Characteristics which enable a plant to evade, tolerate or recover from the attacks of insects, under conditions that would result in greater injury to other plants of the same species, have been recognized during a period of about one and one-half centuries. Host resistance to insects is now recognized as an important scientific field and has attracted much attention in recent years.

The choice of varieties with reference to their ability to avoid insect damage was observed as early as 1788 in the United States by Isaac Chapman, who later advocated the cultivation of wheat varieties having an early growth habit as a means of reducing damage caused by the hessian fly, *Phytophaga destructor* Say. George Lindley (1831) recommended the Winter Majetin and Siberian Bitter-Sweet varieties of apple because of their resistance to the serious apple pest, woolly aphid, *Eriosoma lanigerum* Hausm. under conditions in England. The grape *phylloxera*, *Phylloxera vitifoliae* Fitch, was discovered on an American vine in 1854 by Asa Fitch (Börner 1921) and in 1869 (Feytaud 1920) the high degree of resistance of American vines to this insect was discovered. Since these pioneer observations many similar examples have been recorded. A recent survey of the literature on the subject of host resistance shows that records of resistance have been reported on nearly 100 plant species, and over 100 different insect species are involved.

IMPORTANCE OF RESISTANCE.—The development of varieties of crop plants that are immune to insect attack and also equal in yielding ability and quality to those now in use would be one of the most economical insect control measures because no special effort or expense is necessary on the part of the grower. However, immune varieties are extremely rare and what is called resistance often implies little more than a low degree of susceptibility to attack. That is, according to some of the literature, resistance may be so high as to confer practical immunity or may be so low as to be merely a degree of susceptibility.

It is quite evident that the factors which control or influence resistance or susceptibility are extremely varied. The expression of genetic factors responsible for resistance is often modified by environmental conditions. Resistance to one insect species does not usually imply resistance to some other insect species, and in some cases a variety that is resistant to one biological form of an insect species is highly susceptible to another.

In mentioning a few of the factors responsible for the complex nature of host resistance to insects, it is not intended that the importance of this field of research be minimized, or inferred that host resistance is the only important insect control measure. It does, however, have sufficient promise to warrant attention in general insect control, and in plant breeding programs. In many cases, it is necessary to select strains of plants that have only a fair degree of resistance combined with many other desirable characteristics rather than those that have the highest possible resistance. Other effective control measures often can be used to advantage in conjunction with resistant varieties.

A knowledge of the factors contributing to immunity or resistance and the conditions which influence these factors, is valuable but not wholly essential in

[1] Cooperative investigations of the U.S. Dept. of Agriculture, Illinois Agricultural Experiment Station, and Illinois Natural History Survey.

[2] Associate Agronomist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, U.S. Dept. of Agriculture.

breeding plants for insect resistance. It is highly probable that even the earliest plant breeders were unconsciously selecting for resistance to insects in developing high yielding, good quality crops. A good variety is one that usually reaches maturity and produces a satisfactory yield in spite of insects, diseases, and other adverse factors that beset it.

ORGANIZATION OF THE BREEDING PROGRAM.—The interest of entomologists and plant breeders in the nature of insect resistance in cultivated plants, and the possibility of developing insect resistant varieties of crop plants has been stimulated in recent years. The necessity for cooperation between entomologist and plant breeder is now generally recognized by both groups and has been expressed in the literature on numerous occasions. For various reasons, however, the present status of cooperation leaves much to be desired. Leach (1940) in discussing the need for cooperation between the entomologist and the plant pathologist in studying insect transmission of plant diseases, states that it is one thing to talk of cooperation and another thing to cooperate. He further remarks that so much has been said and written in recent years about cooperation in research that the word, to some extent, has fallen into ill repute. Cooperation often works much better on paper than in practice. In order to avoid the difficulties of cooperation, we often plead for coordination of effort. This sounds much better but is often more difficult, for it requires a great deal of earnest cooperation before we can have successful coordination. Despite all the various difficulties, however, there is and has been a fair amount of real and successful cooperation in breeding for insect resistance.

The failure or lack of cooperation may be caused by many different factors. According to Leach (1940) the human or personal element is perhaps the most common of them all and the most difficult to overcome. Other causes may be administrative, or traditional. Cooperative work is sometimes attempted on the principle of strict division of labor in which all entomological work is done by the entomologist and all agronomic work done by the agronomist. This type of cooperation is often doomed to failure. In the study of plant resistance to insects, such strict division of labor is not practicable. For the greatest success, the invisible, though very real, wall separating the two fields of research must be broken down. This may be rather difficult, but it can be done.

Leach (1940) has suggested that a first step in this direction would be a liberalization of the narrow professional viewpoint. The limitation of professional fields may simplify some of the problems of organization, education, and experience, but it is not conducive to the solution of problems involving more than one of these fields. The necessity for well-defined spheres of research with corresponding responsibility and authority is recognized. Such responsibility and authority are necessary, not only for efficient administration, but also for the guild spirit so important in scientific research. Nevertheless, when attempts are made to draw too sharp a line between related fields of activity, many problems of vital importance and significance must be neglected.

A second step would be a modification of our educational procedure so that research workers would be given the viewpoint and training in techniques necessary for the solution of the problem in hand. The worker should have a thorough knowledge in the essentials of both entomology and plant breeding. Instead of placing the emphasis upon training entomologists or plant breeders, some of the workers should be given training and viewpoint necessary for the solution of the particular kind of problem, namely, the role of host resistance in reducing insect damage. It is not proposed that we train mental giants who can master both fields of knowledge, but rather workers who have a sufficient grasp of the essentials of both sciences for the solution of this particular kind of problem. When these qualifications are combined in one man, many of the difficulties of cooperation will be avoided.

Breeding cultivated plants for insect resistance does not necessarily involve a special breeding program. It is not fundamentally different from breeding for various other plant characteristics which contribute to high yields of a quality product efficiently produced. Many plant characters may contribute toward resistance and many of these characters are interrelated with other desirable plant characters which may not necessarily contribute to-

wards resistance. The fact that genetic segregation for all characters occurs simultaneously makes it highly undesirable to limit a breeding program to insect resistance alone. Breeding for insect resistance should, therefore, be included in a more generalized plant breeding program.

METHODS OF BREEDING FOR INSECT RESISTANCE.—There are four general procedures for the utilization of host resistance in plant improvements. These are:

(1) *Introductions* from either foreign countries or other localities, which often provide a source of greater resistance than may exist in local strains.
(2) *Selection* of strains from varieties or introductions or hybrids to improve resistance and retaining desirable agronomic characteristics.
(3) *Hybridization* between resistant species or varieties and those not resistant but possessing otherwise desirable characters.
(4) *Grafting* of otherwise desirable but susceptible species or varieties upon resistant strains.

Introductions.—There may be no need of attempting to produce a variety which is insect resistant if the resistance desired can be found in some variety already grown in another locality or country. However, it is recognized that an introduced variety, while possessing resistance, may be poorly adapted to its new locality.

There are numerous examples of increased insect resistance being obtained from introductions. Monteith & Hollowell (1929) reported resistance of soy bean introductions to the leaf hopper *Empoasca fabae* (Harr.) and it was found that these introductions varied widely in damage suffered from this insect. They report that Mammoth Yellow is subject to severe dwarfing and decided yellowing under conditions where Tarheel Black suffered practically no injury. Johnson & Hollowell (1935) reported on a more extensive test of soy bean introductions. They concluded that the glabrous introductions were heavily infested with *E. fabae*, were stunted in growth to about one foot in height, and had curled leaves with yellow necrotic margins. The appressed-hairy introductions, on the other hand, were less heavily infested, and, while their leaves were crinkled and slightly yellowed at the margins, the plants attained a final height of 2 feet or more without evidence of marked stunting. The rough-hairy varieties attained a height of approximately 30 inches each season and were practically free from leaf hoppers and their leaves showed no symptoms of hopper injury. They also suggested the possibility of establishing leaf hopper resistant strains by selection of the hairy plants from segregating introductions.

Harlan (1916) working in the West Indies reported on the leaf blister mite, *Eriophyes gossypii* Banks, resistance of several cotton varieties. It was found that 25 introductions showed considerable resistance. Five of these were from Brazil, four from St. Croix, eight from St. Vincent, five from southern Grenadines, and one each from St. Thomas, Dominica, and Tortola. All of the varieties were native to the region from which they were introduced.

The introduction of Maiz Amargo corn from South America into the European corn borer, *Pyrausta nubilalis* Hbn., area of Michigan further illustrates the possible value of introductions in an insect resistance breeding program. Marston & Dibble (1930) in reporting the resistance of Maiz Amargo stated that in all of the domestic strains tested no significant differences in infestation were found which might justify a belief that any of them were markedly resistant to corn borer attack. Corn borer moths introduced on Maiz Amargo plants growing in outdoor cages laid many eggs on the cage but only about 150 on the plants and only one live borer could be found when the corn was mature. Under similar cage conditions, corn borer moths deposited great numbers of eggs on native corn plants and the plants were completely destroyed. From crosses of the South American Maiz Amargo with domestic varieties of corn, hybrids were produced which showed high resistance to corn borer infestation. Maiz Amargo is not adapted to Michigan conditions nor is it a desirable variety agronomically. Consequently it was crossed with adapted and desirable strains of corn in order to utilize its borer resistance.

Atlas sorgo, a variety of forage sorghum was developed at the Kansas Station primarily to overcome some of the agronomic weaknesses of the popular variety, Kansas Orange. Later, however, Snelling & Dahms (1937) and Snelling *et al.* (1937) reported the high resistance of Atlas sorgo to the chinch bug, *Blissus leucopterus* (Say), and the variety has been introduced into many chinch bug infested sections where

it has increased in acreage and popularity.

Selection.—Selection is the simplest method of breeding for insect resistance and merely involves the reservation for succeeding crops of those plants which show some degree of resistance. For the successful use of this method it is necessary that part of the host plant population have genetic resistance and that there is a thorough insect infestation. The plant selection method is used to isolate the most resistant strain of a commercial variety or introduction, and obviously it is limited by the amount of genetic resistance carried by the mixed variety or introduction.

There are many examples of increasing the insect resistance of varieties of crop plants by selection. Selection naturally is most effective under conditions of heavy infestation by the insect. Artificial methods of producing insect infestation materially facilitates the progress that may be made and it is in this field that the cooperation of the entomologist and the breeder may be most effective. A few examples are mentioned here to indicate what has been accomplished through this method of breeding.

Harlan (1917) made selections from Seredo cotton which were immune to the black scale, *Saissetia nigra* Nietn., in the West Indies. The immunity of the selections was attributed to the fact that the scale would not feed on them.

DeLong & Jones (1926) reported the selection of a strain of Houghton gooseberry that is apparently resistant to the attacks of the gooseberry witch-broom aphid, *Kakimia houghtonensis* (Troop); and this selection gives great promise for control. For three years these plants were uninfested and aphids transferred to them did not injure them. Horticulturists have not been able to distinguish these from the parent Houghton gooseberry plants, which are subject to heavy aphid injury, except in the presence of an aphid infestation.

Painter *et al.* (1931) found early in their investigations on the resistance of winter wheat to the hessian fly that varieties, selections, and hybrid lines, whether homozygous or heterozygous for agronomic characters, may be mixed populations so far as a reaction to hessian fly is concerned. The varieties Illini Chief and Fulcaster were studied most intensively in this respect. It was shown by these investigators that some of the Illini Chief and Fulcaster selections possessed high resistance to the hessian fly, while others grown in the same tests were somewhat susceptible.

Snelling *et al.* (1937) have shown that some varieties of sorghum which are apparently homozygous for agronomic characters but which have never been subjected to selection under chinch bug infestation are heterozygous for the genetic factors governing resistance or susceptibility to this insect. Selections were made from the varieties Chiltex and Darso which possessed considerably greater resistance than the parent varieties. These resistant selections appeared identical with the parental varieties in agronomic characters and apparently can be recognized as distinct from the parent only when grown in the presence of chinch bugs.

Hybridization.—Hybridization is a necessary step in combining the desirable characters from two or more strains. The process on the whole is more laborious and sometimes less certain than selection. However, the recombination of characters following cross-fertilization may produce a sort which is more desirable than either parent, whereas selection limits the breeder to the particular combinations of germ plasm existing in a mixed population of similar strains differing from one another principally in the desired character.

There are numerous examples of the recombination of insect resistance with other desirable characters through hybridization followed by selection. The examples involve both inter-specific and inter-variety hybrids. Barnes (1931) has shown that certain species of *Salix* are immune from injury by the button-top midge, *Rhabdophaga heterobia* H. Lw. Three hybrid varieties selected from the cross *S. viminalis* × *S. purpurea* were uninjured by this insect.

Collins & Kempton (1917) reported the results obtained from crossing dent corn resistant to the corn ear worm, *Heliothis armigera* (Hbn.) with susceptible sweet corn. Sweet seeded types with long husks were selected. Several of the progenies were much less subject to injury from the corn ear worm than the commonly grown commercial varieties of sweet corn. Schwartze & Huber (1937) and Huber & Schwartze (1938) published on the high

resistance of the Lloyd George raspberry to the insect vector *Amphorophora rubi* Kalt. of the mosaic disease of red raspberries. Six selections from the resistant Lloyd George and susceptible Cuthbert cross were completely resistant and three selections from the resistant Lloyd George and susceptible Latham cross were resistant. Nineteen hybrids involving susceptible parents were all susceptible. Spinks (1929) produced several families of strawberry seedlings by hybridization that showed marked resistance to the strawberry aphid, *Capitophorus fragaefolii* (Ckll.). The variety Tardive de Leopold was used as the resistant parent.

Jepson & Evans (1935) developed by hybridization a variety of sugar cane that produced satisfactory yields under heavy infestations of *Lachnosterna smithii* Arrow. They state that this hybrid variety although heavily infested, tolerated injury and yielded twice as much as the best of the control varieties. Painter *et al.* (1931) showed that certain strains of wheat selected from hybrids are as resistant to hessian fly as the resistant parent. Several crosses between resistant and susceptible varieties were studied.

Snelling *et al.* (1937) reported the results obtained from an attempt to produce a chinch bug-resistant variety of grain sorghum. A cross between Kansas Orange sorgo (resistant) and Dwarf Yellow milo (susceptible) was made specifically to combine the agronomic characters of milo with the chinch bug resistance of Kansas Orange. The F_4 population was grown under conditions of an extremely heavy chinch bug infestation and only one plant survived. Selection was continued in the progeny from this individual plant and Kans. Sel. 24–136 was developed and has shown greater chinch bug resistance than several hundred varieties and strains with which it was later compared. This selection is lacking in several desirable agronomic characters but is of importance as a source of chinch bug resistant germ plasm for use in breeding work.

Grafting.—Grafting is probably the oldest recognized method of utilizing the insect resistance of one variety and the otherwise desirable qualities of another. It has been previously mentioned that Lindley (1831) recommended the Winter Majetin and Siberian Bitter-Sweet varieties of apple because of their resistance to the serious apple pest, woolly aphid, in England. It was later discovered that the Northern Spy variety was also immune. For many years following the discovery of immunity from the woolly aphid the two varieties Winter Majetin and Northern Spy have served as rootstocks for most of the apple varieties grown in England, Australia, New Zealand, and much of continental Europe. In recent years rootstocks of immune hybrid seedlings have also been used.

The importance of grafting in the utilization of the resistance of the American vine to the grape phylloxera is well known. According to Bioletti (1901) the most satisfactory method of combating phylloxera is the use of resistant vines, because it is applicable to all conditions and is the most economical. Bonnet (1925) stated that there are two general methods of establishing a resistant vineyard. One consists of producing grafted resistant vines in a nursery and planting them in the vineyard and the other in planting the resistant vines in the vineyard to be grafted later. The first method is cheaper and more desirable because it gives a more uniform vineyard and better yields.

Attempts to produce resistant hybrids of fruiting value equal to the European vine are still unsuccessful. The only known practical method of dealing with phylloxera in an infested district lies in the use of grafted plants, that is, the grafting of desirable varieties on rootstocks of resistant varieties. A resistant rootstock that is suitable for all climates and soils has not been found and a large number are in general use.

Thompson (1926) has pointed out the possibility of reducing damage to cherries by the peach and prune root borer, *Synanthedon opalescens* (H. Edw.), by proper selection of rootstocks. Borers were found only in the roots and the crown below the union of the bud and root in cherries budded to *Prunus mahalab* rootstock. Seedling cherries and cherries budded to seedling rootstock were free from attack although planted in the immediate vicinity of infested trees.

Harlan (1917) has utilized grafting in his studies on cotton resistant to the black scale. Seredo cotton is resistant to the black scale, while Sea Island is susceptible. When Sea Island was budded on Seredo the scion was very badly attacked by the

scale. When Seredo was budded on the susceptible Sea Island, the resistance of the scion was not influenced by the stock and remained immune. Immunity appeared to be partially dominant in hybrids between the two varieties.

As shown by the examples mentioned, the search for and utilization of host resistance to insects, through the use of well established methods of plant breeding and of propagation, is an important and valuable means of preventing crop losses due to insects. Although in many cases it may not be possible to find or develop crop varieties resistant to specific insects, the favorable results to date in many instances indicate the importance of investigating this method of control and justify the increased interest in this field now prevalent.—2-19-41.

LITERATURE CITED

Barnes, H. F. 1931. Further results of an investigation into the resistance of basket willows to button gall formation. Ann. Appl. Biol. **18**: 75–82.

Bioletti, Frederic T. 1901. The Phylloxera of the vine. Calif. Agr. Expt. Sta. Bul. **131**.

Bonnet, L. O. 1925. Phylloxera resistant vineyards. Calif. Agr. Expt. Sta. Cir. **288**.

Börner, C. 1921. Zur Heimatfrage der Reblaus (on the question of the original habitat of the vine louse). Zeitschr. Angew. Ent. Berlin **8**(1): 163–7. (Abstracted from Rev. Appl. Ent.)

Chapman, Isaac. 1826. Some observations on the hessian fly; Written in the year 1797. Mem. Phila. Soc. Prom. Agr. **5**: 143–53.

Collins, G. N. and J. H. Kempton. 1917. Breeding sweet corn resistant to the corn earworm. Jour. Agr. Res. **11**: 549–72.

DeLong, D. M., and Merlin P. Jones. 1926. Control measures for the Houghton gooseberry aphid, with special reference to plant resistance. JOUR. ECON. ENT. **19**: 40–3.

Feytaud, J. 1920. La Question Phyloxerique. La Crise des Porte-Greffes en Espagne. (The Phylloxera question. The crisis of grafted vines in Spain.) Bul. Soc. Vulg. Zool. Agr. (Bordeaux) **19**: 97–100, 113–6.

Harlan, S. C. 1916. Notes on resistance to cotton leaf-blister mite with special reference to budded cottons, and to cotton hybrids. West Indian Bul. **16**: 78–82.

Harlan, S. C. 1917. A note on resistance to black scale in cotton. West Indian Bul. **16**: 255–6.

Huber, Glen A., and C. D. Schwartze. 1938. Resistance in the red raspberry to the mosaic vector. *Amphorophora rubi* Kalt. Jour. Agr. Res. **57**: 623–33.

Jepson, W. F., and H. Evans. 1935. Un essai preliminaire sur la resistance des varietes de cannes a l'attaque du *Phytalus*. Rev. Agr. Maurice **81**: 97–101, Port Louis.

Johnson, H. W., and E. A. Hollowell. 1935. Pubescent and glabrous characters of soy beans as related to resistance to injury by the potato leaf hopper. Jour. Agr. Res. **51**: 371–81.

Leach, Julian Gilbert. 1940. Insect transmission of plant disease. McGraw-Hill Book Co., Inc. New York and London.

Lindley, George. 1831. A guide to the orchard and kitchen garden. Longman, Rees, Orme, Brown and Green, London.

Marston, A. R., and C. B. Dibble. 1930. Investigations of corn borer control at Monroe, Michigan. Mich. Agr. Expt. Sta. Spec. Bul. **204**.

Monteith, Jr., John, and E. A. Hollowell. 1929. Pathological symptoms in legumes caused by the potato leaf hopper. Jour. Agr. Res. **38**: 649–77.

Painter, Reginald H., S. C. Salmon, and John H. Parker. 1931. Resistance of varieties of winter wheat to hessian fly (*Phytophaga destructor* Say.), Kans. Agr. Expt. Sta. Tech. Bul. **27**.

Schwartze, C. D., and Glen A. Huber. 1937. Aphid resistance in breeding mosaic escaping red raspberries. Sci. **86** (2224): 158–9.

Snelling, Ralph O., and Reynold G. Dahms. 1937. Resistant varieties of sorghum and corn in relation to chinch bug control in Oklahoma. Okla. Agr. Expt. Sta. Bul. **232**.

Snelling, Ralph O., Reginald H. Painter, John H. Parker and W. M. Osborn. 1937. Resistance of sorghums to the chinch bug. U.S.D.A. Tech. Bul. **585**.

Spinks, G. T. 1929. Families of strawberry seedlings bred for resistance to aphis. Agr. & Hort. Res. Sta. (Univ. of Bristol) Ann. Rept. 1929, pp. 17–27.

Thompson, B. G. 1926. The peach and prune root borer injurious to cherries. JOUR. ECON. ENT. **19**: 779–80.

Grapevines and cuttings may be admitted into Oregon when accompanied by an inspection certificate stating that the plants have originated in a Phylloxera-free area or have been given a hot-water treatment or an oil-and-nicotine dip. Prior to the amendment of the quarantine, which became effective March 24, 1941, no provision was made for entry of grapevines unless they originated in an area free from this pest.

Fumigation requirements for bare-rooted host plants of the oriental fruit moth shipped to Oregon from the infested States during the dormant period, have been modified to provide a minimum dosage of 2 pounds of methyl bromide per 1,000 cubic feet of space at 70°F for 4 hours; or 3 pounds at 60°F for 4 hours. The quarantine amendment providing for these modifications became effective March 24, 1941.

Breeding Corn for Resistance to Insect Attack

J. H. Bigger,[1,2] *Urbana, Illinois*

Through the hundreds of years of its use as a food for men and animals the corn plant undoubtedly developed a material degree of resistance to many of the insects which are now known as pests. Under the more or less casual cultivation by the Indians and their predecessors, this must have been true for the crop to survive as an important food of these races.

Much of the natural resistance must have been retained in the crop in its early use by the white settlers of the American continents. This condition is borne out by the findings of Flint & Hackleman (1923), McColloch and Brunson (Parker & Painter 1932), and Hayes & Johnston (1925) that well established varieties or strains of corn and grasses were able to grow and produce crops under conditions of great abundance of the chinch bug, *Blissus leucopterus* (Say).

Since the first decade of this century and until the early part of the past decade plant breeders and crops specialists attempted to improve the varieties of corn in use by selecting for certain morphological characteristics which they deemed desirable. Unfortunately much of this selection was carried on in the absence of, and without much regard for, insect infestation, so that the improvement or retention of resistance was purely a matter of chance. Under these circumstances progress was very limited. This work was carried on by selection from open-pollinated plants. The result was that many resistant plants that may have been present were pollinated by susceptible plants and the resistance thereby diluted.

Since the beginning of the decade just past there has been increased use of controlled pollination methods in the development of the kinds of corn now in use. There has also been an increased realization of the importance of having insect resistant parentage in the hybrids being developed for commercial use.

Preferential Feeding.—Observations on preferential feeding of insects go back much further than even relatively modern attempts to improve corn. Over 60 years ago Riley (1877) noted differences between the injury by grasshoppers, *Locustidae*, to corn and sorghum which illustrated this choice of food by the grasshoppers. Between that time and 1905 there are apparently no published statements with regard to this point. In that year Forbes (1905) observed that corn leaf aphids, *Aphis maidis* Fitch, showed a definite preference for broom corn and other sorghums over field corn. In making notes on corn earworm, *Heliothis armigera* (Hbn.) in 1910 Headlee (1910) noted the preference of the adults for corn silks and observed that the time of planting affected the infestation due to the fact that the moths apparently preferred to lay their eggs on the silks of corn planted in midseason rather than on the silks of corn planted at earlier or later dates. At the Illinois Station in 1917, Gernert (1917) was growing teosinte and teosinte-corn hybrids. He reported at that time a definite preference of both the corn root aphid, *Anuraphis maidi-radicis* (Forbes), and the corn leaf aphid, *Aphis maidis* Fitch', for corn over the teosinte or teosinte-corn hybrids. In fact, he stated that at no time during the four-month period of observation did he find these aphids on teosinte or crosses, even though they were present on the corn in adjacent rows. During the same year J. R. Doerschuk, County Agent of Randolph County, Ill. (Flint 1921), called the attention of Illinois Station workers to the fact that a variety of corn being used by farmers in the north end of that county was capable of withstanding the attacks of chinch bugs although other varieties were being almost completely destroyed.

In brief, the period prior to and possibly including 1917 was one of observation, during which it became apparent to several observers that insects do show a distinct preference for certain kinds or types of food plants or that plants show a differential response to insect attack. The foundation for organized research relative to insect resistance was laid during this period, but little real progress was made.

Early Organized Work.—Then followed a period when organized attempts

[1] J. H. Bigger, Associate Entomologist, Illinois State Natural History Survey Division.

[2] The author wishes to acknowledge the cooperation and assistance of all other speakers on this program, and of several others who made helpful suggestions with regard to contents and organization of material.

were made to locate strains or varieties of corn resistant to the attack of various insects. Differences in both plant and insect reaction appeared. Probably the earliest really fruitful effort on a definitely organized schedule to study the interrelated reaction between corn and insects was the work of Hinds (1914) with the rice weevil, *Sitophilus oryzae* (L.). He demonstrated, as a result of experimental study, that two varieties grown side by side, all other cultural practices being similar, varied greatly in susceptibility or resistance to injury, and observed that the relative length and tightness of the husk on the ear appeared to be the determining factor. Ears with longer and tighter husks had a lower infestation than those with short, loose husks. Results shown in this report have been corroborated by other workers during more recent years (Cartwright 1930; Phillips & Barber 1931).

In 1918 Flint & Hackleman (1923) followed up the observations of Doerschuk and during that year and succeeding ones were able to pick from among locally adapted varieties several which demonstrated tolerance to attack of second brood chinch bugs. They suggested that this tolerance might be due to the relative vigor of the plants.

McColloch (1921) did some work of a similar nature on corn leaf aphids in Kansas and reported that where he grew varieties side by side in the fields certain ones showed severe injury while others apparently suffered no injury. The most apparent characteristic of the plants which seemed to be associated with this condition was earliness or lateness of the variety; the later varieties showing the heavier infestation. This condition was not true throughout the entire planting because at least one variety showed a marked reduction of infestation over at least two others which required approximately the same growing period.

The corn earworm, came in for some of this type of study and several workers (Kyle 1918; McColloch 1920; Phillips & King 1923; Ditman & Cory 1936; Baker 1936, *et al.*) reported that both the percentage of infestation and the extent of damage by larvae were influenced by length and tightness of husk and that the time and period of silking were also influencing factors. Varieties with a long, tight husk, late varieties, or those having as brief a period of silking as possible were recommended as being those which escaped considerable of the earworm infestation.

Early studies with the European corn borer, *Pyrausta nubilalis* (Hbn.), were, to some extent, of the same nature. Combined variety and date of planting tests were carried on for a period of years and it was found that great differences in infestation and damage existed between varieties planted on the same date and also for the same variety planted on different dates (Huber 1926; Huber *et al.* 1928a; Patch 1929; Neiswander & Huber 1929; Meyers 1930). Corn at a more advanced stage of development was found to be more attractive for oviposition by the moths, as shown by the greater numbers of eggs laid, and also conducive to higher rates of survival of the borer. Differential rates of plant breakage, due to destruction of the tissues by the borer, also were demonstrated among different strains infested at different stages of development.

It was also found that the ultimate amount of borer infestation of corn was influenced by the soil type (Huber 1939; Huber *et al.* 1928b). The variation in soil type was reflected in the rate of plant development which resulted in the differences in infestation, survival, and damage.

This type of research developed more or less at the same time that the agronomists and plant breeders were using the mass selection and ear-to-row methods of corn improvement, and entomologists, taking their cue from them, used the same methods. The projects were developed to a great extent as individual projects by men working alone. Research men were individualists. Each attempted to correlate the variable infestations which he found in plants with some apparent morphological character. This era predated the great cooperative program which has developed since that time.

MODERN APPROACH.—More or less coincident with the most recent of the work previously mentioned came the development of corn improvement by the use of inbred lines and general acceptance of the fact that controlled parentage was practical in developing commercial hybrids for use by farmers. The conception dawned upon, or was forced upon, entomologists that inherent and not readily apparent characteristics of corn, other than mor-

phological ones, might be responsible for, and used to advantage in, developing resistance to insect attack. These innovations ushered in the numerous cooperative programs involving entomologists, plant breeders, physiologists, chemists, and soils specialists which are now in progress, and were more or less presaged by the observation of Collins & Kempton (1917) who stated, with reference to the corn earworm, that " . . . at least a part of the immunity is the result of chemical differences, perhaps the presence of some volatile substance distasteful alike to the moths and the larvae." Whether this statement is literally true or not is beside the immediate point which is that some characteristics of the plant other than morphological were indicated as affecting infestation and damage by insects.

When plant breeders proved that yield, quality, type of ear, kernel, and many other factors were inherent in inbred lines and transmissible to commercial hybrids, entomologists started a search for inherent characteristics responsible for insect resistance. The program naturally divides itself into four phases: (1) A search for insect resistance in inbred lines now in use; (2) a search for new germ plasm possessing insect resistance; (3) the determination of the basic principles responsible for resistance; and (4) the combination of resistance to more than one insect species, together with other desirable characters in the same inbred lines. The last of these may, in some cases, constitute a fifth phase of the work. Such a project necessarily calls for cooperation of scientists in several fields and has resulted in the development of the cooperative programs previously mentioned.

The resistance of inbred lines of corn to the attack of second brood chinch bugs was first reported in 1934 (Holbert *et al.* 1934). The inbred lines were grown in Illinois during 1933 in top cross combination, and during 1934 (Holbert *et al.* 1935) as inbreds and in top cross, single cross, and double cross combinations. As a result of these tests it was reported that some inbred lines contained in their genetic complex dominant factors for chinch bug resistance while others apparently carried factors for chinch bug susceptibility and that resistant lines transmitted resistance to their progeny. Corroborative studies were made in Kansas and Oklahoma (Painter, *et al.* 1935). Resistance or susceptibility of corn to the attack of second brood chinch bugs is measured by records of the comparative numbers of bugs present, by the relative percentage of plants killed, and by comparative yields of strains grown under comparable conditions of environment and infestation. This characteristic is attributable to preference of the insects for one strain rather than another in some cases, and to tolerance of attack by the plant in others. Tolerance may, in some cases, be due to vigor of the plant. It may frequently be influenced by adaptation of the plant to local soil and other environmental conditions (Snelling & Dahms, 1937). The first phase of the research program affecting chinch bug resistance has been fairly well completed. The second phase, a search for new resistant germ plasm, is in progress. Some efforts have been made to determine the reason for resistance, so far with little success. A search for lines which may be resistant to both chinch bugs and the corn earworm is being conducted.

The first attempt to breed corn for resistance to the corn earworm through hybridization was reported by Collins & Kempton (1917). From crosses of long-husked field corn with short-husked sweet corn, strains of long-husked sweet corn were developed which possessed a high degree of resistance to the earworm. Some of the progeny of these crosses were low both in the number of larvae present and in amount of damage per larva. The resistance shown by these strains was transmissible from parent to offspring and suggested, as previously quoted, that some factor or factors other than easily seen morphological characters were responsible for the differences in infestation. Except for Poole (1935, 1936, 1937), Painter (Painter & Brunson 1932, 1940), Burk (Burk *et al*, 1936), Blanchard,[1] and their co-workers, other students of the earworm problem apparently neglected to take these unseen inherent factors into consideration. The work of the investigators listed above indicates that there are significant inherent differences, in the percentage of ears infested and the relative amount of damage done, which are not necessarily associated with husk characteristics or time of flowering, but which

[1] Blanchard, R. A., J. H. Bigger, and R. O. Snelling. 1941. Resistance of corn strains to the corn earworm. (*In manuscript.*)

apparently are due to less obvious factors in the genetic complex of many open pollinated and inbred lines of corn. Earworm resistance is also shown to be transmitted from resistant parents to their offspring, and it is indicated that the resistance of certain lines may be due to an accumulation of factors.

In the survey of the field of available material, certain inbred lines of corn have been shown to be consistently resistant to earworm attack, and a number of investigators are trying, with reasonable success, to isolate highly resistant germ plasm. Germ plasm with a degree of resistance approaching immunity has not yet been found. A search for this should be continued using more highly refined methods than those used previously. At present an attempt is being made in Illinois to combine resistance to earworm and to southern corn rootworm, *Diabrotica duodecimpunctata* (F.), in the same line. Some of this work involves resistant inbred lines with desirable agronomic characters and some involves resistant lines which may necessitate incorporation with more agronomically desirable inbreds.

Since 1926 (Meyers, 1937) there has been continuous study relative to the production of commercial hybrids of field corn resistant to the European corn borer. Early investigation showed that some hybrids were far superior to locally adapted, open pollinated varieties in yield and in their ability to resist damage by this insect. With this as a starting point, Patch, working at the Toledo Laboratory of the Bureau of Entomology and Plant Quarantine, and Huber, Neiswander, and Meyers of the Ohio Agricultural Experiment Station, proceeded to make a survey of the available germ plasm. This is still in progress and all available inbred material suitable in any way to the environmental conditions of the area in which the borer is a problem are being put to a critical test. It was shown early in these tests (Patch 1937; Ficht 1936; Meyers 1928) that certain inbred lines and combinations exhibited a marked degree of resistance to the borer. Rather close study of these lines was made in an attempt to determine the factors contributing this resistance. To date it has not been found. Nevertheless, the knowledge gained has been put to good use and there are now available to the farmer, hybrids with desirable agronomic characters combined with a high degree of resistance to corn borer. A very realistic attitude is apparent among the workers in the eastern portion of the Corn Belt. They are using to best advantage all of the suitable germ plasm available, sorting out the hybrids suitable for use under corn borer conditions, at the same time recognizing that soil conditions and maturity of the plants during moth flight are important factors in any resultant infestation. They are making their recommendations to farmers with all of these conditions in mind.

The search for new germ plasm and the factors responsible for resistance, and the effort to improve existing material are being continued. In addition to the studies of field corn, worth while progress is being made (Schlosberg 1939) with sweet corn, though that project has been conducted only a few years. It is now known that resistance to the attack of the corn borer is inherent in some inbred lines of corn, that it is transmissible to the progeny of these lines, that the adults of the borer show preference for some lines over others for oviposition, that the larvae survive better on some than others, and that some lines are more tolerant to infestation than others. Research by various foreign workers (Rouband 1928; Hase 1929; Ellinger & Chorine, 1930) has tended to support certain of these findings. It has recently been demonstrated (Bottger 1940) that "metamorphic development of the insect was directly affected by nutrition," and that the nutritive qualities of corn internodes varied "as between strains tested." Patch says that borer resistance in field corn has been found to be due to multiple factor differences.

Resistance to injury by the southern corn rootworm, has been found in certain inbred lines of field corn. First observations on this point were made in 1935 (Bigger *et al.* 1938) when it was shown that many double cross hybrids were superior in their ability to stand erect in the field, following severe root pruning by this insect, to other hybrids or open pollinated varieties. Further and more intensive studies were made during the period of 1937 through 1939.[1] Both preference of the adults for certain strains and differen-

[1] Bigger, J. H., R. O. Snelling, and R. A. Blanchard. 1941. Resistance of corn strains to the southern corn rootworm *Diabrotica duodecimpunctata* (F.). *Jour. Amer. Soc. Agron.* (*In press.*)

tial response of the plants to larval attack were demonstrated. These have not been shown to be correlated. Resistance to larval attack has been measured by the amount of lodging of inbred lines and of single crosses in fields where infestation and root pruning were known to have occurred. Resistance of susceptibility to attack of the southern corn rootworm has been shown to be an heritable character. A survey of much of the available inbred material in the Corn Belt has been made. New breeding material carrying rootworm resistance factors is in progress of production. An attempt is being made to determine the factor responsible for resistance and to combine this resistance with corn earworm resistance.

The apparent vulnerability of certain inbred lines of corn to attack by the corn leaf aphid is an important characteristic to plant breeders, since controlled pollinations are very difficult with lines susceptible to attack. Studies of the relative resistance or susceptibility of many inbred lines of corn have been recently published. By measuring the percentage of plants infested at four stations in Illinois during two years (Snelling *et al.* 1940) and one station in Indiana during one year (Walter & Brunson 1940), it has been shown that there are great differences in the amount of infestation present on different corn inbreds. The data indicate that this characteristic is consistent and heritable, though some lines may not be uniform in their reaction. There are some data suggesting the presence of multiple factors as being responsible for the reaction of the lines.

The 1936-38 grasshopper outbreak gave an opportunity for some study of the differential attractiveness of various strains of corn to these insects. Workers at the Kansas station were able to obtain information on the reactions of inbred lines of corn in top crosses, three-way crosses and double crosses (Brunson & Painter 1938). Highly significant differences in amount of injury, as measured by the estimated percentage of leaf destroyed, were recorded. From the data obtained it appears that there is a genetic basis for the differential injury reported. It is noteworthy that inbred lines developed from open pollinated varieties which had frequently been exposed to grasshopper attack were the ones showing the smallest amount of damage. "It is suggested that natural selection operating in the development of adapted varieties of corn has tended to intensify resistance to grasshoppers and other natural insect pests of the region" (Brunson & Painter 1938).

With all these advances toward the use of strains of corn resistant to insect attack, there has been one unfortunate circumstance. So far as is known at present, with one exception, the fact that an inbred line is found to be resistant to one insect does not permit the assumption that it is resistant to any other insect. Each line must be tested individually under the attack of each insect to which it is normally exposed in order to determine the extent of its resistance or susceptibility. There are a number of cases in which lines are resistant to two or even three insects, but each is an individual case. Since resistance is relative, however, it is sometimes possible to make crosses of somewhat resistant lines in which the resistance of the combination is built up to a satisfactory point. This possibility is well known to producers of corn hybrids and is being utilized by them.

The exception to this condition has been reported by Huber & Stringfield (1940), who have found significant positive correlations in the degree of strain susceptibility to the corn leaf aphid and the European corn borer. Those working on insect resistance hope that other such relationships will be found. If resistance to one insect could be depended upon as evidence of resistance to another, even in the absence of the second insect, more rapid progress in the development of resistance to both pests could be made in case either one were present. There seems to be no physiological or genetic barrier to the combination of resistance to various insects or for such combinations to include any group of characters desirable for other reasons.

CONCLUSION.—An entire revolution of the general idea of the importance of resistance of corn to insect attack and the methods of studying it has occurred during the past decade. We have developed from the isolated, and sometimes ridiculed efforts of a few individuals in widely separated areas to an integrated program of cooperative effort by various state and national organizations to arrive at the ultimate purpose of producing high yielding,

sound corn, with desirable agronomic characteristics, which also has the ability to make a satisfactory showing under conditions of rather severe insect infestations. Today entomologists, agronomists, physiologists, chemists, and plant breeders are all working together toward the same end, and, at least in some cases, state lines have been disregarded and workers in different states are cooperating with each other and with federal agencies. Truly there is some reason to claim that recent progress in the study of resistance of corn to insect attack has been an outstanding development. The progress already made offers a challenge to all entomologists and cooperating organizations to take full advantage of the possibilities of this phase of biological control for the reduction of losses due to the ravages of insect pests of corn and other crops.—1-11-40.

LITERATURE CITED[1]

Barber, G. W. 1936. The corn earworm in Southeastern Georgia. Ga. Agr. Expt. Sta. Bul. **192.**

Bigger, J. H., J. R. Holbert, W. P. Flint and A. L. Lang. 1938. Resistance of certain corn hybrids to attack of Southern corn rootworm. JOUR. ECON. ENT. **31:** 102–7.

Blanchard, R. A., J. H. Bigger and R. O. Snelling. 1941. Resistance of corn strains to the corn earworm. Jlur. Amer. Soc. Agron. (Manuscript presented for publication.)

Bottger, G. T. 1940. Preliminary studies of the nutritive requirements of the European corn borer. Jour. Agr. Res. **60:** 249–57.

Brunson, Arthur M., and Reginald H. Painter. 1938. Differential feeding of grasshoppers on corn and sorghums. Jour. Amer. Soc. Agron. **30:** 334–46.

Burk, Earl F., C. B. Cross and Ephriam Hixon. 1936. Variety test of sweet corn and its resistance to corn earworm and smut injury. Proc. Amer. Soc. Hort. Sci. **33:** 502–4.

Cartwright, O. L. 1930. The rice weevil and associated insects in relation to shuck lengths and corn varieties. S. C. Agr. Expt. Sta. Bul. **266.**

Collins, G. N., and J. H. Kempton. 1917. Breeding sweet corn resistant to the corn earworm. Jour. Agr. Res. **11:** 549–72.

Ditman, L. P., and E. N. Cory. 1936. The corn earworm. 3rd Report Md. Agr. Expt. Sta. Bul. **399:** 77–90.

Ellinger, T., and V. Chorine. 1930. Report on a corn variety test under corn borer conditions. Internat. Corn Borer Invest. Sci. Rept., Chicago, Ill., III: 99–100.

Ficht, G. A. 1936. Relative resistance of selected strains of corn to European corn borer. JOUR. ECON. ENT. **29:** 687–91.

Flint, W. P. 1921. Chinch bug resistance shown by certain varieties of corn. JOUR. ECON. ENT. **14:** 83–5.

Flint, W. P., and J. C. Hackleman. 1923. Corn varieties for chinch bug infested area. Ill. Agr. Expt. Sta. Bul. **243.**

Forbes, S. A. 1905. The corn leaf-louse, *Aphis maidis* Fitch. State Ent. Ill. Rept. **23:** 123–33.

Gernert, W. B. 1917. Aphis immunity of teosinte—Corn Hybrids. Science **46:** 390–2.

Hase, Albrecht. 1929. Report on corn borer experiment, 1927–1928. Internat. Corn Borer Invest. Sci. Rept., Chicago, Ill. II: 77–84.

Hayes, W. P., and C. O. Johnston. 1925. The reaction of certain grasses to chinch bug attack. Jour. Agr. Res. **31:** 575–83.

Headlee, T. J. 1910. Notes on the corn ear-worm. JOUR. ECON. ENT. **3:** 149–57.

Hinds, W. E. 1914. Reducing insect injury to seed corn. Ala. Agr. Expt. Sta. Bul. **176:** 49–68.

Holbert, J. R., W. P. Flint and J. H. Bigger. 1934. Chinch bug resistance in corn, an inherited characteristic. JOUR. ECON. ENT. **27:** 121–4.

Holbert, J. R., W. P. Flint, J. H. Bigger and G. H. Dungan. 1935. Resistance and susceptibility of corn strains to second brood chinch bugs. Iowa State Col. Jour. Sci. **9:** 413–25.

Huber, L. L. 1928. European corn borer. How variety and planting date of corn affects the European corn borer. Ohio Agr. Ext. Serv. Bul. **8:** 1–4.

Huber, L. L., D. J. Caffrey and C. R. Neiswander. 1928a. The trend of European corn borer research. Ohio Bi-Mo. Bul. **130:** 3–8.

Huber, L. L., C. R. Neiswander and R. M. Salter. 1928b. The European corn borer and its environment. Ohio Agr. Expt. Sta. Bul. **429:** 128–43.

Huber, L. L. 1939. The European corn borer and corn hybrids. Ohio Agr. Exp. Sta. Bi-Mo. Bul. **197:** 26–8.

Huber, L. L., and G. H. Stringfield. 1940. Strain susceptibility to the European corn borer and the corn leaf aphid in Maize. Science **92**(2382): 172.

Kyle, C. H. 1918. Shuck protection for ear corn. U.S.D.A. Farmers' Bul. **708.**

McColloch, James W. 1920. A study of the oviposition of the corn earworm with relation to certain phases of the life economy and measures of control. JOUR. ECON. ENT. **13:** 242–55.

McColloch, James W. 1921. The corn leaf aphid (*Aphis maidis* Fitch) In:—Kansas. JOUR. ECON. ENT. **14:** 89–94.

Meyers, M. T., J. S. Cutler and C. R. Neiswander. 1928. Corn breeding in relation to the corn borer problem. In:— Ohio Agr. Expt. Sta. Bul. **429:** 143–7.

[1] A bibliography of approximately 500 references dealing with plants resistant to insect attack is to be published in the future, probably 1941, by Ralph O. Snelling in *Botanical Review*.

Meyers, M. T. 1930. Breeding varieties of corn resistant to the European corn borer. Ohio Agr. Expt. Sta. Ann. Rept. 48, Bul. **446**: 32–4.

Meyers, M. T., L. L. Huber, C. R. Neiswander, F. D. Richey and G. H. Stringfield. 1937. Experiments on breeding corn resistant to the European corn borer. U. S. Department of Agriculture Tech. Bull. **583**.

Neiswander, C. R., and L. L. Huber. 1929. Height and silking as factors influencing European corn borer population. Ent. Soc. Amer. Ann. **22**: 527–42.

Painter, R. H., A. M. Brunson and J. H. Parker. 1932. The resistance of crop plants to insect injury. Kansas Agr. Expt. Sta. Bien. Rept. **6**: 99.

Painter, R. H., R. O. Snelling and A. M. Brunson. 1935. Hybrid vigor and other factors in relation to chinch bug resistance in corn. JOUR. ECON. ENT. **28**: 1025–30.

Painter, R. H., and A. M. Brunson. 1940. Differential injury within varieties, inbred lines and hybrids of field corn caused by the corn earworm, *Heliothis armigera* (Hbn.). Jour. Agr. Res. **61**: 81–100.

Parker, J. H., and R. H. Painter. 1932. Insect resistance in crop plants. 6th Internat. Cong. Gen. Proc. **2**: 150–2.

Patch, L. H. 1929. Some factors determining corn borer damage. JOUR. ECON. ENT. **22**: 174–83.

Patch, L. H. 1937. Resistance of a single-cross hybrid strain of field corn to European corn borer. JOUR. ECON. ENT. **30**: 271–8.

Phillips, W. J., and K. M. King. 1923. The corn earworm, its ravages on field corn and suggestions for control. U.S.D.A. Farmers' Bul. **1310**.

Phillips, W. J., and G. W. Barber. 1931. The corn earworm as an enemy of field corn in the Eastern states. U.S.D.A. Farmers' Bul. **1651**.

Poole, C. F. 1935. Corn-earworm resistance in maize varieties at Davis, California. Amer. Soc. Hort. Sci. Proc. 1934. **32**: 453–7.

Poole, C. F. 1936. New sweet corns resistant to earworm. Amer. Soc. Hort. Sci. Proc. 1935. **33**: 496–501.

Poole, C. F. 1937. Resistance to corn earworm injury in the Charleston, South Carolina area. Amer. Soc. Hort. Sci. Proc. 1936. **34**: 566–9.

Riley, C. V., A. S. Packard, Jr., and Cyrus Thomas. 1877. The Rocky Mountain Locust. U. S. Ent. Comm. Ann. Rept. **1**: 252.

Roubaud, E. 1928. Biological researches on *Pyrausta nubilalis* (Hbn.). Int. Corn Borer Invest. Sci. Repts. 1927–1928. Internat. Livestock Exposition, Chicago, Ill., pp. 1–40.

Schlosberg, Morris, and W. A. Baker. 1939. Sweet corn resistant to larval survival of the European corn borer. JOUR. ECON. ENT. **32**: 530–4.

Snelling, R. O., and R. G. Dahms. 1937. Resistant varieties of sorghum and corn in relation to chinch bug control in Oklahoma. Okla. Agr. Expt. Sta. Bul. **232**.

Snelling, R. O., R. A. Blanchard and J. H. Bigger. 1940. Resistance of corn strains to the leaf aphid, *Aphis maidis* Fitch. Jour. Amer. Soc. Agron. **32**: 371–81.

Walter, E. V., and A. M. Brunson. 1940. Differential resistance of corn strains to the leaf aphid, *Aphis maidis* Fitch. JOUR. ECON. ENT. **33**: 623–8.

Breeding Wheat and Alfalfa for Resistance to Insect Attack

C. M. PACKARD, *U. S. Department of Agriculture Bureau of Entomology and Plant Quarantine*

The effort to find or produce wheat varieties resistant to insect injury has been concerned mainly with resistance to the hessian fly *Phytophaga destructor* (Say). The existence of fly-resistant wheat was recognized over 150 years ago (Anonymous 1797; Chapman 1826; Fitch 1846, 1847; Havens 1792). The circumstances surrounding the discovery in 1782 of a yellow-bearded, hard-stemmed resistant variety called Underhill are described by Fitch as follows:

"Quite early in its history, the important fact became accidentally discovered, that certain varieties of wheat are capable of withstanding its attacks. In the year 1781, a prize schooner loaded with wheat, was taken in the Delaware River, and carried into New York, whence the cargo was sent to the mill of Isaac Underhill, near Flushing, Long Island, to be ground. Mr. Underhill's own crop of the previous year having been so entirely destroyed that he had no grain for seed, he took what he required for sowing from this cargo, and reaped therefrom upwards of twenty bushels per acre, whilst few of his neighbors for miles around had any to reap, so calamitous were the operations of the fly. To his praise be it recorded, he distributed his entire crop, in small quantities, and at a moderate price, among his neighbors, for seed; and all who made use of it were similarly successful. The 'Underhill wheat' at once became noted, for effectually resisting the attacks of the fly, and for many years subsequently, as we shall have frequent occa-

sion to notice, was eagerly sought for and successfully cultivated, where all other varieties of this grain failed."

Fitch also discusses several other varieties of wheat reported to be resistant and the factors thought to be responsible for their resistance. Since Fitch's time a number of workers have reported observations on the resistance of certain varieties to the hessian fly. These have been summarized by McCulloch & Salmon (1918) and by Painter *et al.* (1931).

The first systematic observations for the purpose of finding fly-resistant varieties of wheat appear to have been those of Woodworth (1891), who examined 125 varieties being grown at the California Experiment Station at Berkeley. These studies were followed by the work of McColloch & Salmon (1918) and Painter *et al.* (1931) in Kansas, Haseman & McLane (1921) in Missouri, Packard (1928) in California, Rockwood & Reeher (1933) in Oregon, Kiesselbach *et al.* (1933) in Nebraska, Foster & Jeffrey (1937) in British Columbia, Caldwell & Compton (1938) in Indiana, Tchesnokov (1939b) in Russia, and others.

These studies revealed (1) that a number of wheats do show decided resistance to the hessian fly, at least one, the durum variety FPI-94587, even approaching immunity; (2) that none of the wheats possessing this resistance are commercially desirable except in restricted areas; and (3) that with most of them fly resistance varies in different localities. These discoveries indicated the possibility and desirability of producing more highly resistant and commercially acceptable wheats by means of selection and crossing, and work of this character was begun by Painter & Jones in Kansas, Cartwright in California, and Packard & Noble in Indiana, all in cooperation with the Federal and State agronomists and plant pathologists working in those States.

Thousands of wheat varieties and strains have been tested by these investigators and others. These tests showed that fly resistance occurs in a number of varieties and served to determine those most desirable for use as breeding material. Among the wheats found to be the most promising were selections of Dawson, Kawvale, Marquillo, FPI-94587, and Illinois No. 1. In tests conducted in 1936, the results of which are unpublished, the following percentages of plants of these varieties were found infested as compared with approximately 100 per cent in susceptible checks: Dawson, 0.3 at Bird's Landing, Calif.; Kawvale, 0 at Bird's Landing, 26 at Junction City, Kans., and 10 at Lafayette, Ind.; Marquillo, 13 at Junction City and 10 at Lafayette; FPI-94587, 0 at Junction City and Lafayette and 1 at Manhattan, Illinois No. 1-W38, 1 at Lafayette, 8 at Junction City, and 11 at Bird's Landing.

The durum wheat FPI-94587, of spring habit as are all durum wheats, is the only one that has shown almost complete immunity in all areas and under all conditions. Marquillo and Illinois No. 1 are also spring wheats, and Dawson, although a winter wheat, shows little resistance to the hessian fly in the soft winter-wheat region where injury by the fly is most prevalent. The problem in that region thus became one of breeding the fly resistance of the spring varieties into commercially satisfactory winter wheats without carrying along the undesirable characters. Dawson, however, is highly resistant to the fly in California, and at the time the breeding program was begun there it was the most promising source of fly resistance. Since the only satisfactory wheats in central California are of spring habit, the problem there was the opposite of that encountered in the Middle West, namely, the transference of resistance from a winter wheat into commercially desirable spring wheats.

The results of the intensive breeding work during the past decade, involving the testing of thousands of varieties and selections, have shown (1) that fly resistance can be successfully transferred from spring to winter wheats and vice versa; (2) that the factors for resistance are transmitted in accordance with genetic laws (Cartwright & Wiebe 1936, Noble *et al.* 1940, Painter *et al.* 1940); (3) that these factors are not linked with undesirable characters; (4) that resistance to diseases as well as to the fly can be combined in a single homozygous line; and (5) that desirable commercial wheats possessing high resistance to the fly and to the common fungous diseases can be produced.

The partially resistant variety Kawvale was released for commercial production in Kansas in 1931 and now leads all other

varieties in acreage in eastern Kansas. A new strain of Big Club, highly resistant to the fly in California, is now being increased for distribution in that state and a strain possessing resistance to both fly and bunt is expected to be ready for release there in 1941. Several lines of both hard and soft red winter wheats possessing hessian fly resistance, tolerance to the jointworm, and resistance to leaf rust, stem rust, and mildew, together with excellent agronomic characters, are now being developed in Kansas and Indiana. Similar investigations have been inaugurated in Illinois, Ohio, and Pennsylvania. These developments have been made possible only through cooperation between the entomologists concerned and the Federal and State agronomists and plant pathologists, without which real progress in work of this kind cannot be made.

Not much is known about the particular plant characters responsible for fly resistance in wheat (Anderson & Brown 1936; Jones 1940; Painter *et al.* 1940). Unattractiveness of the plants to ovipositing flies, low survival and inhibited development of feeding larvae, as well as ability of the plant to withstand larval feeding, are all known to be involved. Obviously, resistance to the hessian fly must be due to certain anatomical, physiological, or biochemical attributes possessed by the resistant plants, but their identity is still more or less a mystery. Therefore, it is not yet possible to select resistant plants or lines on the basis of visible characters. The only way yet known of selecting for resistance is to make sure that the plants are amply exposed to infestation and to examine them individually for the presence of the fly after the infestation has had opportunity to develop.

Although good fortune has, on the whole, attended efforts to find and improve fly-resistant varieties of wheat, numerous difficulties have been encountered. Chief among these is the difficulty of consistently obtaining significant infestations in the test plots. When weather conditions are unfavorable, wheat germination, fly activity, and infestations are very low, and a whole year's work may be lost. Various measures must be taken to overcome this difficulty, such as locating the plots where conditions are especially promising for infestation, heeling in large quantities of heavily infested stubble or volunteer wheat around the test plots, and irrigating the plots and source material in dry seasons in order to induce germination of the wheat and emergence of the flies. Simultaneous sowing in different localities are often made for the purpose of obtaining significant results and of ascertaining varietal reactions under widely different conditions. Such tests include the use of so-called uniform fly-test nurseries, in which the same promising lines or varieties are sown in a number of regions each year by several cooperating agencies.

Another complication has resulted from the occurrence of distinct biological strains or races of the fly itself, which differ in their ability to infest different varieties of wheat. Painter (1930) was the first to publish evidence of this phenomenon in the hessian fly, although unpublished reports by J. W. McColloch indicate that he suspected its existence. The occurrence of variation in the fly, as well as in the host plant, is now generally accepted as fact, although for many years differences in degree of resistance of the same variety when grown in different regions were thought to be due to the environmental effect on the host plant rather than to variation in the fly. The complexity of the procedure for producing dependable resistant wheats is greatly increased by the existence of biological races of the fly. It is necessary to test these wheats in different areas where they will be exposed to local varieties of the fly. Furthermore, it may be necessary to isolate and propagate the fly strains artificially, much as the plant pathologists do their many strains of rusts, in order that the interrelations of fly strains and wheat strains may be unraveled by means of closely controlled tests. Possibly in no other way can success in the growing of wheats that are fly-resistant in all areas be assured.

The fact that the resistance of many strains of wheat varies with the environment is an added complication. Wheats that are highly resistant under normal outdoor conditions may become highly susceptible when grown in a warm, moist greenhouse. This would indicate to the layman that fly resistance is purely a matter of environment and not one of inheritance, but the geneticists assure us otherwise. It seems that genetic characteristics of either the insect or its host can

be emphasized or obscured by environmental conditions.

A knowledge of these complications aids in the establishment of procedures essential to success in producing dependable fly-resistant wheats, and it also indicates what may be expected as to the stability of resistant varieties when grown in the field. Although the development of highly resistant, commercially desirable varieties may now be expected, the perfection of completely immune varieties may not be attainable. Not only are the resistant varieties likely to become mixed with susceptible ones when grown in proximity to other wheats but, if large acreages of them are grown to the exclusion of more susceptible varieties, the few flies of a strain capable of surviving on them may increase in abundance until such resistance as the wheat may possess is no longer effective. However, the possible development or persistence in nature of such fly strains seems doubtful and, with the information now available, it may be feasible through suitable breeding methods to forestall this eventuality. Even if such an outcome cannot be prevented, it should be possible to continue the production of new varieties of wheat possessing resistance to the strains of fly that may become prevalent in this manner. Be that as it may, the progress made thus far encourages the belief that the production of highly resistant, if not completely immune, varieties is entirely practicable and offers promise of a more efficient and economical method of preventing losses due to the hessian fly than any previously available.

The resistance of wheats to other insect pests has received much consideration and would appear to justify more intensive and systematic investigation. Observations by Jones (1937) indicate material differences in the reactions of different wheat varieties to the chinch bug, *Blissus leucopterus* (Say). Allen & Painter (1937), Bigger (1938), Dunham (1934), Gilbertson (1925), and Webster (1889) have recorded observations on resistance to the wheat stem maggot, *Meromyza americana* Fitch. Tchesnokov (1939a) in Russia has reported on the distribution of various forms of wheat and their resistance to the frit fly, *Oscinella frit* L. Kemp (1934) in Canada and Schegolev (1926) in Russia have published information on the resistance of solid-stemmed wheats to the wheat stem sawfly, *Cephus cinctus* Nort. Painter *et al.* (1940) report resistance or tolerance to the wheat jointworm, *Harmolita tritici* (Fitch). Doubtless other instances could be cited, but those mentioned will serve to show the extent of the field and the possibilities.

Control methods for insects attacking wheat and similar crops of low value per acre are necessarily confined to inexpensive procedures, such as cultural measures. For this reason the discovery or development of resistant varieties of these crops is particularly desirable, since their practical use would involve little, if any, extra cost and would free the farmer from the restrictions and expense imposed by more or less unsatisfactory cultural control measures.

No symposium on insect resistance in crop plants would be complete without some mention of recent developments regarding certain varieties and selections of alfalfa. Searls (1932) reported resistance in alfalfa to the potato leafhopper, *Empoasca fabae* (Harr.), and Poos made observations, as yet unpublished, indicating that varieties differ in reaction to infestation by this insect. Jewett (1932, 1936), however, did not find any distinct differences in resistance to the leafhopper in several strains of alfalfa on which he made observations in Kentucky.

In the case of the pea aphid, *Macrosiphum pisi* (Kalt.) a high degree of resistance has been found in some alfalfa varieties and selections, and the possibility of utilizing this discovery in a practical way seems good. Blanchard & Dudley (1934) were perhaps the first to report resistance in alfalfa to this insect. Working independently in California and Wisconsin during the period 1930 to 1933, they discovered individual plants on which this aphid was unable to survive and breed. In the spring of 1934 Painter & Grandfield (1935) noted wide differences in degree of infestation and injury of plants growing in experimental plots and fields at Manhattan, Kans. Dean & Smith (1935) observed that the variety Ladak and individual plants of Kansas Common and some other varieties differ in resistance to this insect and state that the selection or breeding of a resistant variety offers a possible method of control. In 1937 Ladak was released and recom-

mended by the Kansas Agricultural Experiment Station for use on farms in Kansas. It has also been found resistant to the pea aphid in Washington (Eichmann & Webster 1940).

Dahms & Painter (1940) published the results of a study on the rate of reproduction of the pea aphid on resistant and susceptible alfalfa plants and their progeny. This work, together with that of L. G. Jones in California and W. T. Emery in Kansas, now in progress in collaboration with plant breeders and geneticists in those States, indicates that a high degree of aphid resistance occurs in certain alfalfa plants and that it is transmissible in accordance with well-known genetic laws and methods of breeding.

Little is known, however, about the specific characters responsible for the resistance of alfalfa to the pea aphid. In the breeding of alfalfa for aphid resistance complications similar to those encountered in wheat breeding occur. It is impossible to distinguish resistant plants on the basis of morphological characters, and the reactions of both host plant and insect vary in different environments. Furthermore, the problem of segregating and propagating pure lines of alfalfa is more difficult than in the case of wheat. Alfalfa is not normally self-fertilized, as is wheat, and thus more tedious and careful work is involved in conducting and controlling this part of the breeding program. On the other hand, alfalfa can be produced vegetatively, and the final product perhaps would not have to be quite so uniform as in the case of wheat. Some strains of alfalfa possess greater resistance than might be commercially necessary, and a few are practically immune. Progress in developing resistant varieties will no doubt be slower, but no reason has yet appeared why success may not eventually be expected.—1-30-41.

LITERATURE CITED

Anonymous. 1797. Hessian fly. Encyclopedia Britannica, Ed. 3, vol. 8: 489–95. Edinburgh.

Allen, Merle W., and Reginald H. Painter. 1937. Observations on the biology of the wheat-stem maggot in Kansas. Jour. Agr. Res. **55**(3): 215–38.

Anderson, Dean C., and Hubert M. Brown. 1936. Studies on hessian fly infestation and some characters of the wheat culm. Amer. Soc. Agron. Jour. **28**(6): 479–83.

Bigger, J. H. 1938. Resistance of certain wheat varieties to attack by the wheat-stem maggot, *Meromyza americana* Fitch. Amer. Soc. Agron. Jour. **30**(5): 448.

Blanchard, R. A., and John E. Dudley, Jr. 1934. Alfalfa plants resistant to the pea aphid. JOUR. ECON. ENT. **27**(1): 262–4.

Caldwell, R. M., and L. E. Compton. 1938. Wheat breeding for combined resistance to disease and the hessian fly. Ind. Agr. Expt. Sta. Ann. Rept. **1938**: 39, 41–2.

Cartwright, W. B., and G. A. Wiebe. 1936. Inheritance of resistance to the hessian fly in the wheat crosses Dawson X Poso and Dawson X Big Club. Jour. Agr. Res. **52**(9): 691–5.

Chapman, Isaac. 1826. Some observations on the hessian fly; written in the year 1797. Phila. Soc. Prom. Agr. Mem. **5**: 143–53.

Dahms, R. G., and Reginald H. Painter. 1940. Rate of reproduction of the pea aphid on different alfalfa plants. JOUR. ECON. ENT. **33**(3): 482–5.

Dean, Geo. A., and Roger C. Smith. 1935. Insects injurious to alfalfa in Kansas. Kan. State Bd. Agr. Bien. Rept. **29**: 202–49.

Dunham, R. S. 1934. Stem maggot injury among wheat varieties. Amer. Soc. Agron. Jour. **26**(11): 978–80.

Eichmann, R. D., and R. L. Webster. 1940. The influence of alfalfa on the abundance of the pea aphid on peas grown for canning in southeastern Washington. Wash. Agr. Expt. Sta. Bul. **389**.

Fitch, Asa. 1846. Insects injurious to vegetation IV. The hessian fly. Amer. Quart. Jour. Agr. and Sci. **4**: 244–64.

Fitch, Asa. 1847. Insects injurious to vegetation V. The hessian fly. Amer. Quart. Jour. Agr. and Sci. **5**: 1–27.

Foster, W. R., and C. E. Jeffrey. 1937. Resistance of winter wheats to hessian fly. Canad. Jour. Res. Sec. C., Bot. Sci. **15**(4): 135–40.

Gilbertson, G. I. 1925. The wheat-stem maggot. S. D. Agr. Expt. Sta. Bul. **217**.

Haseman, L., and S. R. McLane. 1921. An investigation of the hessian fly resistant qualities of different varieties of wheat. Mo. Agr. Expt. Sta. Bul. **179**: 26–7.

Havens, Jonathan N. 1792. Observations on the hessian fly. N. Y. Soc. Agr. Trans., Arts and Manufactures, pt. **1**, pp. 89–107.

Jewett, H. H. 1932. The resistance of certain red clovers and alfalfas to leafhopper injury. Ky. Agr. Expt. Sta. Bul. **329**: 155–72.

Jewett, H. H. 1936. A leafhopper pest of clover and alfalfa. Ky. Agr. Expt. Sta. Circ. **44**.

Jones, Elmer T. 1937. Differential resistance to chinch-bug attack in certain strains of wheat. Kan. Acad. Sci. Trans. **40**: 135–42.

Jones, Elmer T. 1940. A discussion of fly resistance in certain wheat varieties. Kan. Acad. Sci. Trans. **43**: 243–65.

Kemp, H. J. 1934. Studies of solid stem wheat varieties in relation to wheat stem sawfly control. Sci. Agr. **15**(1): 30–8.
Kiesselbach, T. A., Arthur Anderson and C. A. Suneson. 1933. Winter wheat varieties in Nebraska. Neb. Agr. Expt. Sta. Bul. **283.**
McColloch, James W., and S. C. Salmon. 1918. Relation of kinds and varieties of grain to hessian-fly injury. Jour. Agr. Res. **12**(8): 519–27.
Noble, W. B., W. B. Cartwright and C. A. Suneson. 1940. Inheritance of resistance to hessian fly. JOUR. ECON. ENT. **33**(3): 580–1.
Packard, C. M. 1928. The hessian fly in California. U. S. Dept. Agr. Tech. Bul. **81.**
Painter, Reginald H. 1930. The biological strains of hessian fly. JOUR. ECON. ENT. **23**(2): 322–6.
Painter, Reginald H., and C. O. Grandfield. 1935. Preliminary report on resistance of alfalfa varieties to pea aphids, *Illinoia pisi* (Kalt). Amer. Soc. Agron. Jour. **27**(8): 671–4.
Painter, Reginald H., Elmer T. Jones, C. O. Johnson and John H. Parker. 1940. Transference of hessian fly resistance and other characteristics of Marquillo spring wheat to winter wheat. Kan. Agr. Expt. Sta. Tech. Bul. **49.**
Painter, R. H., S. C. Salmon and John H. Parker. 1931. Resistance of varieties of winter wheat to hessian fly, *Phytophaga destructor* (Say). Kan. Agr. Expt. Sta. Tech. Bul. **27.**
Rockwood, L. P., and Max M. Reeher. 1933. The hessian fly in the Pacific Northwest. U. S. Dept. Agr. Tech. Bul. **361.**
Schegolev, V. N. 1926 (1929). European sawfly (*Cephus pygmaeus*) and black sawfly (*Trachelus tabidus*) in Stavropol in 1925. (Abstract). Biol. Abs. **3**(1–3): 227.
Searls, Ed. M. 1932. A Preliminary report on the resistance of certain legumes to certain homopterous insects. JOUR. ECON. ENT. **25**(1): 46–9.
[T]Chesnokov, P. G. 1939a. Relationships between distribution of various wheat forms and their resistance to frit-fly (*Oscinella frit* L.). Acad. des Sci. U.R.S.S. Compt. Rend. (Dok.) **22**(5): 282–6, Eng. ed.
[T]Chesnokov, P. G. 1939b (1940). Spring wheats resistance to hessian fly. Selek. i Semen. **10**(8): 12–13. [Abstract in Biol. Abs. **14:** (7): 1214.]
Webster, F. M. 1889. Does the wheat-stem maggot, *Meromyza americana*, discriminate between different varieties of wheat? Insect Life **2**(2): 87.
Woodworth, C. W. 1891. Variation in hessian fly injury. Calif. Agr. Expt. Sta. Rpt. **1890**: 312–8.

Breeding Vegetables for Resistance to Insect Attack[1]

STANLEY F. BAILEY, *University of California, Davis*

The general subject of plant resistance to insects and diseases has been reviewed by various authors and these reports have been cited elsewhere. We are here concerned only with such work as pertains to vegetable crops. In contrast to the breeding work done with corn, wheat, and legumes, very little concrete information on vegetables is available on which to build a resistance program or to summarize the progress made in this field. As a result of the diversity of vegetables and the frequently transient nature of such annual crops necessitating only temporary insect control measures there is a great lack of fundamental knowledge of the factors involved in resistance and their inheritance. Hence it would appear that vegetable crops offer the greatest opportunity for original work in the field of breeding for insect resistance in crop plants today.

REVIEW OF LITERATURE.—Many of the references found in the literature on insect resistance are without mention or suggestion as to the nature of the resistance or the specific factors concerned. Red Dutch cabbage is known to be resistant to or at least free from attacks of the cabbage root maggot (McColloch 1924 and Mahoney 1934). The Petrosky turnip in Alaska is apparently immune to root maggots (Fairchild 1938). Carter (1937) stated that both mealy-bug toxicity to the pineapple and the plant susceptibility to attack are very variable perhaps due to a "fugitive state" of the plant at the time of infestation. In comparing bait-sprays on tomatoes Marlowe (1937) observed that there was considerable difference in the susceptibility of the two varieties used, to the melon fly, *Chaetodacus cucurbitae* (Coq.). Holdaway (1940) noted a marked difference in the degree of pod infestation of garden (string) bean varieties by this same insect. The Kentucky Wonder was the least damaged. In 1937 the writer noted that the kidney type beans were

[1] The writer wishes to acknowledge the assistance of the members of the symposium in locating several references and for other helpful suggestions brought forward during the preparation of this report.

much more severely damaged by the thrips, *Frankliniella occidentalis* (Perg.), and *Hercothrips fasciatus* (Perg.) than lima beans. Wild lima beans in Puerto Rico (W. K. Bailey 1938) have been observed to be practically uninfested with pod borer, even when grown beside common beans badly injured. In a brief report on resistance in miscellaneous crops, MacLeod (1935) stated that "Most of the lima beans that were tested showed little or no Mexican bean beetle feeding. The potato varieties, Smooth Rural and Blue Victor were significantly more free from flea-beetle injury than were any other varieties tested. Scab-gnat and millipede injuries were less frequent on tubers of Netted Gem and Columbia Russet than on other varieties of potatoes." Hoerner (1938) wrote that the squash bug exhibited preference for certain varieties of winter squashes and that some varieties of summer squashes and pumpkins were fed upon but not injured.

Many more examples of observed resistance in crops other than vegetables have been cited elsewhere. Oftentimes there is no outstanding morphological difference, color contrast, or variation in type or rate of growth between the apparently resistant and the susceptible varieties. Immunity in such instances apparently results from physiological or invisible differences (Felt & Bromley 1931). Undoubtedly many cases of crop plants which actually have a capacity for resistance are overlooked or go unrecorded because there is no visible expression of resistance among varieties. Quite possibly, if the progress of the infestation were closely watched, the resistance might be more evident at certain stages of plant development than at the time when counts were made.

Information on the nature of insect resistance in the potato is more complete, except for the onion, than in any of the few vegetable crops studied from this standpoint. A large number of entomologists have studied hopperburn on potatoes and its relationship to the potato leafhopper. Fenton & Hartzell (1923) believed that the appearance of the hopperburn and the degree of injury were associated with the succulence and stage of growth of the host-plant—at the time the leafhoppers migrated from the weeds. Ball (1919), Maughan (1937), Sleesman & Bushnell (1937) and Allen & Rieman (1939) reported similar findings. Sleesman (1940) found that certain wild potatoes, particularly *Solanum polyadenium*, is highly resistant to the leafhopper and apparently contains some toxin which causes the death of nymphs feeding upon it. Poos & Smith (1931) reported that among the hosts tested *Empoasca fabae* (Harris) preferred potato. In general the rough hairy pubescent varieties within a species of host plant was usually less injured than the non-pubescent or appressed pubescent varieties. Oviposition occurred on all varieties and apparently, therefore, hairiness is not the prime factor in resistance. Schafer (1939) and Trouvelot & Brejoux (1939) have published the results of studies with various species of *Solanum* in comparative feeding tests with the Colorado potato beetle. No cultivated varieties were found to be resistant. *Solanum demissum*, *S. commersonii*, and *S. caldasii* appear to be poisonous to the beetle larvae which develop very slowly and enter a torpor if too much is eaten in a short period. Hanson (1933) tested 8 varieties of potatoes for resistance to the flea beetles, *Epitris cucumeris* Harris and *E. subcrinita* Lec. The beetles exhibit a preference for the weaker plants and the vigorous plants better withstand the injury.

Verschaffelt (1910) observed that cabbage butterflies were more attracted to crucifers having certain mustard oils. Roney (1933) believed that the degree of smoothness of the leaves of turnips was correlated with the amount of aphid infestation. Control measures were more effective on the smooth varieties. The green varieties of celery were found by MacLeod (1933) to be more resistant to tarnished plant bug injury than those bleached. Carter (1927) considered that high osmotic pressure of the plant sap of native weeds insured freedom from attack of the beet leafhopper, *Eutettix tenellus* Bak. The hopper appeared to avoid high concentrations of sap if more suitable food was available. Priesner (1939) theorized that variations in the concentration of cell sap react on the insect by altering the normal balance between osmotic pressure of the absorbing tissues of the alimentary canal and that of the sap " . . . comparatively high concentrations, as is found in older plants, being fatal to at least early stages of sucking insects." Mumford (1930)

thought that the thickness of the epidermis and cuticle of the sugarbeet leaf gave some external protection from the leafhopper.

Davidson (1922, 1923) reported a detailed study of *Aphis rumicis* L. on *Vicia faba* varieties. *Vicia narbonensis* had the lowest susceptibility of the 18 varieties tested. The thickness of the leaf cuticle was mentioned as an agent in preventing injury. Also, the same author (1925) enlarged upon his earlier ideas of the plant-insect relationship and wrote that factors which influence the physiological activity of the plant thereby affect growth and the nature of the cell sap which, through the food factor, affects the progress of the aphid infestation. Such physiological changes are of course caused by temperature, humidity, soil conditions, fertilization, light, and age. Thomas (1940) in summing up the wireworm problem wrote, "In addition to a difference in susceptibility of different species of plants, apparently a difference exists in the amount of damage done by wireworms to varieties of the same plants, especially to grains . . . this immunity may be due to factors outside the plant itself, such as local soil and weather conditions etc. . . . and that the so-called immune varieties might be attacked under other conditions."

The recurved spines on the leaves of string beans were noted by McKinney (1938) as limiting the green peach aphis and thrips infestation on string beans. The insects were impaled on the spines, probably with the aid of the wind. The length of the spines in relation to the size of the insects affected the number thus caught. The same writer observed that the gum-like exudate formed on the tips of short, sticky spines on tomato leaves caught many aphis and thrips and tended to control these pests. Greger (1933) controlled cutworms on cabbage plants by fertilizing the seedlings heavily thereby developing tough stems which after setting out, prevented the cutworms from attacking them. Metzger and others (1934) after an exhaustive study of the susceptibility of plants to attack by the Japanese beetle found that odor and sugar content appear to be the significant factors causing attractiveness to the beetle.

Somewhat in contrast with the above-mentioned inherent causes of resistance as set forth by the various writers, DeLong (1934) believed that immunity in the potato was induced by applying sulfur or Bordeaux. It was postulated that immunity to the potato leafhopper was brought about by plant stimulation caused by the presence of the sulfur and copper sulfate. These materials possibly resulted in the production within the plant of abnormal quantities of a toxic material normally found in the plant in minute amounts, or by some chemical change in the sap.

In the case of thrips resistance in the White Persian onion (Jones *et. al.* 1934, 1935) the nature of the resistance is fairly well understood. Two groups of factors apparently are involved: "one, probably, controls those characters that hold the thrips population to a minimum; the other helps the plant to withstand injury. Two, or perhaps three characters apparently tend to restrict the thrips population—namely, the shape of the leaves, the angle of divergence of the two innermost leaves, and the distance apart of the leaf blades on the sheath column. Probably of considerable importance is the difference in shape of leaves. In most varieties the leaf blades have a flat side; these sides are face to face and, in the young leaves, closely appressed, protecting the larvae against enemies and adverse weather conditions. In White Persian the leaves are almost circular in cross section, reducing protection to a minimum." Likewise, the wide angle between the two innermost emerged leaves, particularly in the young plant, is another White Persian character that helps materially in reducing the protective environment for the thrips to a minimum.

While the above-mentioned characters help restrict the thrips population, other characters, as yet not well understood, help the plants to withstand injury. Leaf color may be a factor in resistance to injury since "typical injury is most prominent in varieties with dark-green foliage; less so in the Spanish types which have lighter-green foliage, and is apparently absent in White Persian which has foliage that is even lighter green that that of the Spanish types. Also, it was thought that a thicker leaf tissue might help to prevent desiccation of the cells adjacent to the injured areas. (It had already been established that the thrips could feed and reproduce normally on the White Persian when

the leaves were artificially appressed.) Measurements were made to determine a possible difference in thickness between leaves of varieties showing different degrees of resistance. When the results were analyzed "the differences between the mean thickness of the Australian Brown and White Persian, and Sweet Spanish and White Persian were found to be significant. The difference between Australian Brown and Sweet Spanish may, however, be unimportant. Leaf thickness alone probably does not account for resistance to injury, because certain White Persian plants had leaves about the thickness of Australian Brown but still without typical injury."

Maughan & MacLeod (1936) reported their findings on a four-year study of thrips resistance in onion varieties and concluded that the Sweet Spanish type is less heavily populated than any other variety. In conclusion they state, "it is most logical to assume that no single factor can be established as the sole reason for the differences in number of thrips found. Avoidance on the part of the thrips angle of contact of the plant leaves, stage of growth of the plants and recovery of the plant tissues from injury all have some bearing on the problem but there are probably other influences also involved. In most instances it is likely that no single term will adequately define all the characteristics of a plant variety which influences its susceptibility to insect attack and injury."

Resistance in the onion to *Thrips tabaci* Lind. in general is apparently more constant when the plants are grown in different climates than is the case in some known examples of insect resistant plants. MacLeod (1933) reported on a study of onion thrips resistance in New York state and classified the Sweet Spanish among those varieties showing greatest resistance. The Yellow Globe Danvers, Southport Red Globe, Ebenezer, Red Wethersfield, and Mt. Danvers varieties were classified as susceptible. These findings coincide with those of the California workers with certain exceptions in other commercial varieties. Sleesman (1935), in Ohio, found the White Persian to be the most resistant and, of the commercial varieties, Sweet Spanish to have the lowest population and Ebenezer and Southport Yellow Globe to have the highest populations. In addition, Australian Brown was somewhat less heavily populated with thrips, as is the case in California. Also, in the inter-mountain region, Wakeland (1936) found that certain strains of Sweet Spanish onions harbored a smaller population of the onion thrips than other commercial strains studied, particularly the Red Globe types, Danvers, and other Sweet Spanish strains observed.

It is indeed fortunate that thrips resistance in the onion holds up so well under different growing conditions since breeding work with locally desirable types can continue with emphasis on disease resistance and agronomic characters. Such progress is now being made in New York, Ohio, Indiana, Iowa, Texas, Louisiana, and California.

While not in the category of vegetables, some work on thrips resistance in gladiolus (Bailey, 1938) may be mentioned as having a bearing on the general problem. Thrips-free bulbs were grown in an isolated area and all 61 varieties were artificially infested in the same stage of development. Based on the degree of injury to the leaves and salability of the spike, the varieties were divided into four groups. The varieties appearing to be the most resistant were Alma Needham, Gay Hussar, Salbach's Pink, Butterboy, Pearl of California, and Magna Blanca. No physical measurements or statistical analysis of the results were compiled. Observations over a period of years in the gladiolus growing areas of California indicate that some or all of the following characters are important in gladiolus resistance to *Taeniothrips simplex* Morison: early blooming, rate of growth, natural vigor, tightness of leaf sheath, toughness of leaves, color of leaves and flowers, and chemical composition of sap. One of the most important factors appears to be the rate of growth or the length of time elapsing between bud formation and blooming. Closely tied up with the rate of growth is, apparently, the amount of sugar in the plant. The slower growing varieties are usually injured most severely and, when stalks are chewed, these varieties are found to be sweeter to the taste of man than the more rapidly growing varieties.

This study of resistance will serve to illustrate several important points. When the gladiolus thrips first came to our attention, flower growers and florists were

greatly concerned about the new pest and no practical control was known. The difficulty of obtaining good control with contact sprays (even when applied weekly) naturally caused one to turn to the possibility of developing resistant varieties. It was shortly realized that there were hundreds of varieties listed and that the popularity of these varieties fluctuated greatly. Also it was soon learned that the genetic constitution of gladiolus was not known. However, as a few seasons passed it was realized that certain cultural practices together with corm fumigation and, more lately, the tartar emetic spray offered a practical solution of the problem of controlling this pest.

SUMMARY OF FINDINGS.—In the majority of the cases cited above the exact nature of resistance is not known. With each individual crop-insect association different factors or combinations of factors appear to be involved. The type and strength of insect mouthparts, oviposition responses, toxic or distasteful substances in the plant fluid, rapidity of growth of the plant and recovery from injury, as well as type of growth, thickness of epidermis, etc., all limit insect activity on its host. Those familiar with the literature in this field know that the causes of resistance are usually arranged under three major headings—physical, chemical, and physiological. Additional classifications have also been set up, as those of Mumford (1931) employing the term epiphylaxis for resistance due to external protective agencies and endophylaxis for resistance resulting from internal protection from biochemical characters. Therefore, while it is possible to arrange plant resistance to insects neatly under various headings, when it comes to analyzing for the factors of resistance and entering into a breeding program, the characters causing resistance do not appear at all comparable (even though certain parallels can be found) and each problem must be treated individually. It will undoubtedly be many years before sufficient concrete data are available upon which to formulate any fundamental conclusions on resistance in vegetable crops.

DISCUSSION.—Criticism is sometimes made of results obtained from comparative infestation data based on plots made up of a number of varieties. It is argued that the insects have been given a choice which would not be the case if only one variety were grown. This would obviously make no difference if the plant fluids were actually toxic or inaccessible. Also, Flint & Bigger (1938) have pointed out that there is always a difference of local opinion as to which is the best variety of a given crop to grow locally. Under normal crop growing conditions more than one strain usually has been present from which the insects might choose. Pure seed laws and other new regulations governing the growing of crops (as is already evidenced with acreage limitations), however, will undoubtedly alter this situation especially where the future release of new varieties is concerned.

One might well be guided in breeding for insect resistance by a number of general rules. Above all, a practical viewpoint should be maintained. If all other types of control have failed over a period of years or the margin of profit in a crop does not permit the use of costly control methods, resistant varieties probably offer the best solution. The need for the development of squash varieties resistant to the squash bug is a good example of this point. This reason for undertaking a breeding program has also been pointed out in the case of the onion thrips (Jones *et al.* 1934). The value of an industry in relation to the expense and effort necessary to a long-time breeding program should likewise be carefully considered. The example of the gladiolus thrips cited above serves as an illustration.

To contribute a fundamental piece of work of real value upon which others can build, the genetic structure of the plants in hand should be known and understood. This is especially desirable since many workers are concerned only with their own local problems and varieties. It is not necessary, however, to know the exact nature of the resistance and the factor causing resistance to incorporate it with desirable agronomic characteristics or to make practical use of the general information. Such is the case in the two oldest and most well-known examples of resistance, namely the grape phylloxera and the Hessian fly. In conclusion may we repeat that vegetable crops probably offer the greatest opportunity today for original work in the field of breeding for insect resistance or the building of superior germ plasm in crop plants.—1-17-41.

LITERATURE CITED

Allen, T. C., and G. H. Rieman. 1939. Occurrence of hopperburn resistance and susceptibility in the potato. Amer. Potato Jour. **16**(6): 139–42.

Bailey, S. F. 1937. The bean thrips. Univ. Calif. Agr. Expt. Sta. Bul. **609**: 34–5.

Bailey, S. F. 1938. Thrips of economic importance in California. Univ. Calif. Expt. Sta. Circ. **346**: 57.

Bailey, W. K. 1938. Resistance of Puerto Rican wild lima beans to pod borers. Puerto Rico Expt. Sta. Rpt. 1938, p. 77.

Ball, E. D. 1919. The potato leafhopper and the hopperburn that it causes. Wis. Dept. Agr. Bul. **23**: 81–3.

Carter, W. C. 1927. Population of *Eutettix tenellus* (Baker) and the osmotic concentration of its host plants. Ecology, **8**(3): 350–62.

Carter, W. C. 1937. The toxic dose of mealy-bug wilt of pineapple. Phytopathology, **27**(10): 971–81.

Davidson, J. 1922. Biological studies of *Aphis rumicis* Linn. Reproduction on varieties of *Vicia faba*. Ann. Appl. Biol. **9**: 135–45.

Davidson, J. 1923. Biological studies of *Aphis rumicis* Linn. The penetration of plant tissues and the source of food supply of aphids. Ann. Appl. Biol. **10**: 35–54.

Davidson, J. 1925. Biological studies of *Aphis rumicis* L. Factor affecting the infestation of *Cicia faba* with *A. rumicis*. Ann. Appl. Biol. **12**: 472–507.

DeLong, D. M. 1934. Insecticidally induced immunity in plants to sucking insects. Science **80**(2075): 320–1.

Fairchild, D. 1938. The world was my garden. Chas. Scribner and Sons, New York, p. 407.

Felt, E. P., and S. W. Bromley. 1931. Developing resistance or tolerance to insect attack. JOUR. ECON. ENT. **24**: 437–43.

Fenton, F. A., and A. Hartzell. 1923. Bionomics and control of the potato leafhopper. Iowa Agr. Expt. Sta. Res. Bul. **78**: 377–440.

Flint, W. P., and J. H. Bigger. 1938. Biological control of insects through plant resistance. Canad. Ent. **70**(12): 244–6.

Greger, H. G. 1933. Resistant cabbage. Market Grow. Jour. **53**: 246.

Hanson, Arthur J. 1933. The potato flea beetles, *Epitris cucumeris* Harris, and *Epitris subcrinita* Leconte. Wash. Agr. Expt. Sta. Bul. **280**: 17–8.

Hoerner, J. L. 1938. Controlling the squash bug. Colo. Agr. Expt. Sta., Press Bull. **93**: 3–4.

Holdaway, F. G. 1940. Differential susceptibility of varieties of garden bean to oviposition by melon fly, *Dacus cucurbitae* Coq. Proc. of Haw. Ent. Soc. 1939, **10**(3): 421–2.

Jones, H. A., S. F. Bailey and S. L. Emsweller. 1934. Thrips resistance in the onion. Hilgardia **8**(7): 215–32.

Jones, H. A., S. F. Bailey and S. L. Emsweller. 1935. Field studies of *Thrips tabaci* Lind. with especial reference to resistance in onions. JOUR. ECON. ENT. **28**(4): 678–80.

MacLeod, G. F. 1933. Some examples of varietal resistance of plants to insect attacks. JOUR. ECON. ENT. **26**: 62–7.

MacLeod, G. F. 1935. Plant-varietal resistance to insect injury. 48th Ann. Rept. Cornell Univ. Agr. Expt. Sta., p. 100.

Mahoney, C. H. 1934. What the plant breeder can and should do for the vegetable grower. Breeding for insect resistance. Proc. Ohio Veg. Grow. Assoc. **19**: 57–9.

Marlowe, R. H. 1937. Susceptibility of two tomato varieties to infestation by *Chaetodacus cucurbitae* (Coq.). Proc. Haw. Ent. Soc. **9**(3): 407–8.

Maughan, Frank B. 1937. Varietal differences in insect populations and injuries to potatoes. Amer. Potato Jour. **14**(5): 157–61.

Maughan, F. B., and G. F. MacLeod. 1936. Further studies of onion varieties and onion thrips. JOUR. ECON. ENT. **29**(2): 335–9.

McColloch, J. W. 1924. The resistance of plants to insect injury. Kans. St. Hort. Soc. Bien. Rpt. **37**: 196–208.

McKinney, K. B. 1938. Physical characteristics on the foliage of beans and tomatoes that tend to control some small insect pests. JOUR. ECON. ENT. **31**(5): 630–1.

Metzger, F. W., P. A. van der Meulen and C. W. Mell. 1934. The relation of the sugar content and odor of clarified extracts of plants to their susceptibility to attack by the Japanese beetle. Jour. Agric. Res. **49**(11): 1001–8.

Mumford, E. P. 1930. On the curly top disease of sugar beet: a biochemical and histological study. Ann. Appl. Biol. **17**: 28–35.

Mumford, E. P. 1931. Studies in certain factors affecting the resistance of plants to insect pests. Science, n.s. **73**: 49–50.

Poos, F. W., and F. F. Smith. 1931. A comparison of oviposition and nymphal development of *Empoasca fabae* (Harris) on different host plants. JOUR. ECON. ENT. **24**: 361–71.

Priesner, H. 1939. A brief note on the relation between the physiological condition of plants and insect attack. Bul. Soc. Fouad Ier Ent. **22**(1938): 279–83.

Roney, J. N. 1933. Truck crop insect investigations. Tex. Agr. Expt. Sta., Ann. Rpt. **46**: 50.

Schafer, P. 1939. Researches and problems connected with the control of the Colorado beetle by breeding. Zeitschrift für Pflanzenzüchtung **23**: 239–322.

Schwartz, M., and H. Müller-Böhme. 1938. [Investigations on the capacity for resistance to *Leptinotarsa decemlineata*, Say, of wild species of plants allied to potato and of crosses between them and cultivated potato.] [Addresses at the Plant Protection Meeting of the German Imperial Biological Institute on 10th February, 1938] Mitt. biol. Reichsanst. pt. **58**: 47–54.

Sleesman, J. P. 1934. Onion thrips (*Thrips tabaci* Lind.). 52nd Ann. Rpt. Ohio Agr. Expt. Sta. Bul. **532**: 41–2.

Sleesman, J. P. 1935. "Tests on the susceptibility of varieties of onions to *Thrips tabaci*, Lind." Entomology. Bul. Ohio Agr. Expt. Sta. **548** (Rep. 1933–34): 39–45.

Sleesman, J. P. 1940. Resistance in wild potatoes to attack by the potato leafhopper and potato flea beetle. Amer. Potato Jour. **17**: 9–12.

Sleesman, J. P., and J. Bushnell. 1937. Variations in nymphal populations of the potato leafhopper on different varieties of potatoes. Amer. Potato Jour. **14**(8): 242–5.

Thomas, C. A. 1940. The biology and control of wireworms. Penn. State Agr. Expt. Sta. Bul. **392**: 71–4.

Trouvelot, B., H. Müller-Böhme, and Lacotte. 1938. Remarques sur le comportement du doryphore *Leptinotarsa decemlineata*, Say, sur des hybrides *Solanum demissum-Solanum tuberosum* (premier note). Rev. Path. veg. **25**, fasc. **4**: 273–6.

Trouvelot, B., and R. Brejoux. 1939. Rapports biologiques entre le doryphore (*Leptinotarsa decemlineata*, Say) et *Solanum demissum* 2e note). Somnolence et reduction d'activite presentees par les larves consommant les feuilles de cette plante. Rev. Path. veg. **26**, fasc. **2**: 142–7.

Verschaffelt, E. 1910. The causes determining the selection of food in some herbivorous insects. Kon. Akad. Wetensk, 546–52, Amsterdam. Proc. Sec. Sc. **13**(1): 536.

Wakeland, C. 1936. Resistance by certain onion varieties to onion thrips. Idaho Agr. Expt. Sta. Bul. **220**: 30–4.

The Economic Value and Biologic Significance of Insect Resistance in Plants[1]

REGINALD H. PAINTER,[2] *Kansas State College, Manhattan*

INTRODUCTION.—Entomologists and plant breeders for many years have been recording, and a few have been studying in detail, the differential injury of insects to plant varieties. Some have made an an attempt to analyze the facts and factors concerned and to utilize the information and the resistant plant selections in insect control. It is perhaps well to consider the accomplishments in this field as they are related to applied entomology and to general biology.

Generalizations on a subject where much of the information is as new as it is in the case of insect resistance in plants must necessarily be tentative and based on present evidence as it can now be interpreted. In the first and most important place it should be acknowledged that insect resistance is not a cure-all but must be fitted carefully to the control of specific insects and into the plant improvement program of particular crops. The development of resistant varieties usually requires a long period of controlled experiments and plant breeding. Hence insecticidal control and, to a lesser extent, other means must remain the first line of defense against injurious insects. On the other hand, results already secured indicate that the possibility of using plant resistance to insects richly deserves careful study for each major insect pest and many minor ones.

The intensity of resistance varies widely from crop to crop with the associated insects. As a result of these differences in resistance the use of resistant varieties falls roughly into three groups.

RESISTANT VARIETIES AS A PRINCIPAL CONTROL METHOD.—There are, in the first place, cases in which insect resistance offers a major means of control. Insects of which this is true are often practically plant parasites with high host specificity. This is true of some aphids and scales, and a few others. That high host specificity is not a necessity for a high degree of insect resistance is suggested by such examples as the relationship of grasshoppers to corn and sorghums (Brunson & Painter 1938)[3] which has been repeatedly observed during grasshopper outbreaks since 1878. If sorghums are almost entirely avoided as food by such a supposedly omnivorous insect as the grasshopper, is it surprising that within a single host species important differences can be found?

The outstanding example of insect resistance as a major means of insect control is the well known case of the grape phylloxera, *Phylloxera vitifoliae* Fitch.

[1] Contribution No. 500, Department of Entomology, Kansas State College of Agriculture and Applied Science, Manhattan, Kansas.

[2] The author is indebted to several of his colleagues and especially to the others appearing on this symposium for suggestions and criticisms.

[3] References to the bibliography are frequently intended only as examples of the points mentioned and are not intended to be exhaustive.

Phylloxera resistant grape vines were sent about seventy years ago from this country to France. These vines still form an important means of control for this insect. Dr. L. O. Howard (1930) in his "History of Entomology" has reported in dramatic detail the damage which the phylloxera did in France and the swiftness of recovery after resistant vines were introduced. While the phylloxera is the best example of resistance as a major method of control other cases are likely to develop out of studies now in progress. In the case of the hessian fly, insect resistance will, if present results are indicative, eventially become the chief, though not the only, available means of control. (Painter *et al.* 1940).

RESISTANCE AS AN ADJUNCT TO OTHER CONTROL MEASURES.—It is as an aid in other control measures that insect resistance is most important and may be most commonly used. This use of resistant varieties involves a careful fitting in with other control measures on the one hand and with the crop improvement program on the other. In the case of chinch bugs we apparently shall always need barriers, where usable, for the protection of young sorghum and corn plants, but resistant varieties of these crops furnish the only available defense against the second and third brood bugs as well as against the few that get by the barriers (Snelling *et al.* 1937; Holber, *et al.* 1935). Used in this way as a control measure, resistant varieties affect a period in the life history of the chinch bug that can be reached in no other manner.

In addition to resistance to insect attack as an adjunct to other means of insect control there is an excellent possibility that it may aid in the control of some of the diseases that are carried by insects. In the breeding for the resistance to the aphid which carries mosaic of raspberries (Schwartze & Huber 1939) a measure of control of the disease has been obtained as well as control of the insect.

REDUCING CHANCE OF RELEASE OF SUSCEPTIBLE SPECIES OR VARIETIES OF PLANTS.—A third group of possibilities for the use of resistant varieties consists of studies which serve to prevent the distribution of new varieties and species that are more susceptible to various insects than those currently grown. Insects concerned in this group are often those capable of feeding on a wide range of hosts, which hosts sometimes show only a low level of resistance.

All corn varieties thus far studied can be destroyed by grasshoppers if these insects are sufficiently plentiful yet there are differences in extent of injury by grasshoppers to corn varieties and hybrids which are highly significant and may, under many circumstances, mean the difference between good yield and crop failure (Brunson & Painter 1938). Surely there are places where it is worth while to consider resistance to grasshoppers, where such information is available, in the choice of inbreds and hybrids, for increase and distribution even though we may not list grasshopper resistance in corn as a control measure of value comparable to poison bait.

In the newer fields of soil conservation many new varieties and species are being introduced or studied, including strains of native grasses. It appears highly important that these should be tested with at least the more important insects in order that species and varieties of plants that will increase our troubles from these pests may not be recommended. Some such information is available for a few insects (Jones 1939; Hays & Johnson 1925) but more is needed.

In the use of crops which show only this low level of resistance instances may occur in which artificial control might be successful with moderately resistant varieties but not with susceptible ones.

RESISTANT VARIETIES AND OTHER PHASES OF APPLIED ENTOMOLOGY.—*Relationship of resistant varieties to general population level of the insect involved.* In addition to the three groupings discussed above there are several other points at which the use of insect resistant plant varieties touches the field of economic entomology. For instance, it has been shown the varieties on which insects feed may exert a large influence on their fecundity and on other phases of their life history (Painter 1936). Chinch bugs raised on various kinds of seedlings laid about 18 times as many eggs on Dwarf Yellow Milo, a variety of grain sorghum, as on Atlas Sorgo, a variety of forage sorghum, and about 25 times as many on Manchuria barley as on Kanred Wheat (Dahms, *et al.* 1936). Differences such as these, although known to be less on more

mature plants, may easily affect the general population level of an insect when a resistant variety becomes sufficiently abundant. Atlas Sorgo was released by the Kansas Agricultural Experiment Station in 1928 and, because of its chinch bug resistance and other desirable qualities, has largely replaced other sorghums in eastern Kansas. One might, therefore, expect an effect on the chinch bug population level. But in this same period the winter barley acreage has likewise increased, and two wheat varieties, Kawvale and Tenmarq, which may be more susceptible to chinch bugs than are older varieties (Jones 1937) have been distributed. Thus possible effects of Atlas Sorgo on the level of chinch bug population may have been largely counteracted by other known crop and varietal shifts. This illustrates the complexities of this problem and also its possibilities.

Not only may one crop and one insect be controlled but where alternate hosts are involved there is a possibility of influencing the insect population level in one crop by planting resistant varieties of an alternate crop. The use of crops to fight chinch bugs is a well known means of control (Flint & Burlison 1920). Isley (1935) has pointed out the relation of hosts to abundance of bollworm, and Sanderson (1939) has studied the relation of different crops to the abundance of *Melanoplus differentialis*. Eichmann & Webster (1940), in a study of the relationship of pea aphids to alfalfa and to canning peas, pointed out that severe infestations of the latter crop are derived from alfalfa. It was found that Ladak alfalfa was resistant in Washington as had previously been reported to be the case in Kansas (Painter & Grandfield 1935) where this variety was released for use by farmers in 1937. Eichmann & Webster suggest the use of resistant varieties of alfalfa for the control of pea aphids on peas. Studies in Kansas and at other stations have resulted in the isolation of several strains much more resistant in laboratory tests than is Ladak (Dahms & Painter 1940) and progress in this control of an insect on two crops by the use of resistant varieties on one may become an actuality in the future.

RELATIONSHIP OF RESISTANT VARIETIES TO INSECT PARASITISM.—There appear to be few cases on record in which a study has been made of the influence of plant host on insect parasitism. Some examples of this influence have been given by Flanders (1940). Bradley & Arbuthnot (1938) record the observation that variations in host habits may produce life cycles of *Chelonus annulipes* Wesmael of several different durations. Seamans & McMillan (1935) have shown that on unfavorable food plants parasitized larvae of the pale western cutworm died before pupation.

The information available indicates that the relationship between resistant varieties of plants and the insect parasites of the pests affected by the plant resistance may take two opposing trends. First, reduction in the population level of the host might make it difficult for the parasites to find and thus would have an adverse effect on biological control by parasites. Second, the profound effect on the physiology of the host which may result from feeding on resistant plants might affect the establishment of insect parasites favorably. Again the effect of resistant plants on host size would influence the prolificacy, size, and perhaps sex of the insect parasite (Flanders 1936, 1939). Thus any relationship between resistant plant varieties and insect parasites cannot be predicted with certainty beforehand but will need to be worked out in each individual case.

RELATIONSHIP OF RESISTANT VARIETIES TO CHEMICAL CONTROL.—There has been a growing volume of evidence of the relationship between food, including resistant plant varieties, and the efficacy of chemical control measures. It has been reported (Phillips & Swingle 1940) that mosquito larvae vary from almost complete susceptibility to complete resistance to rotenone and nicotine in accordance with their previous diet. Compton & Kearns (1937) have stated that "great variation in the susceptibility of red spider to certain sprays has been shown to be closely correlated with the species of plant infested." Swingle (1939) has reported that the per cent of kill by lead arsenate in the case of a leaf feeding insect varied from zero to 98 per cent in accordance with the previous diet of the insect. These effects do not concern the equally important character of pilosity of the plant and its relation to the adherence of dusted arsenicals, as has been studied

in cotton by Dunnam (1936). These data strongly suggest that the combination of chemical control and resistant varieties may prove more effective when control cannot be obtained by either method alone. Such control may come about either through the independent, though cumulative, effect of the two methods or through some effect of the resistant variety on the physiology of the insect making it more easily killed by the insecticide.

INTERRELATIONS OF FACTORS AFFECTING INSECT RESISTANCE IN PLANTS.—Visiting administrators, entomologists, or plant breeders when shown plots demonstrating the effectiveness of insect resistance, most frequently ask "What is the cause of this resistance?". In answer it can only be said that progress is being made in finding out the cause of resistance but that, so far, experimenters have been able to utilize insect resistance in crop improvement and insect control without complete knowledge of the reasons why the plants are resistant. While first studies sometimes indicate a simple explanation of resistance, later ones are likely to point toward a more complex relationship between plant and insect, especially when all resistant varieties are studied. The hairiness of legumes and other plants, for instance, was early indicated as a basic factor in resistance to leaf hoppers (Hollowell *et al.* 1927) but later investigations have shown that, in some cases at least, hairiness accounts for only part of the resistance (Jewett 1932; Poos & Smith 1931; Johnson & Hollowell 1935). Hence, one must frequently deal with a number of causes or mechanisms which result in resistance rather than with a single factor, and in attempting to breed resistant varieties a knowledge of these mechanisms may sometimes be of little use. The insect involved will always be the final judge of whether or not a new variety, selection, or hybrid is really resistant.

A study of recent work in various variety-insect relationships indicates that one or more of three characteristics lie at the basis of most cases of resistance (Painter *et al.* 1940). These three characteristics are often interrelated as indicated in the accompanying diagram. (Fig. 1).

The use of the term *antibiosis* is proposed for those adverse effects on the insect life history which result when a resistant host variety or species is used for food. The effects in the insect take the form of reduced fecundity, decreased

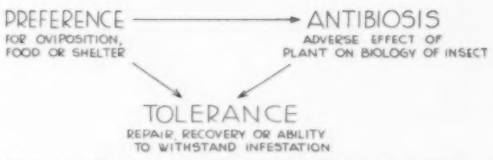


FIG. 1.—Three interrelated characteristics one or more of which is frequently present in resistant varieties.

size, abnormal length of life, and increased mortality, usually in the first instar or in those preceding the adult stage. Various combinations of these effects may be produced.

This basic triangle of resistance relationships usually has been found to represent independent genetic characters which are, however, interrelated physiologically. In any given resistant variety only one of these characteristics may be present but sometimes the others will be found in other varieties and the possibility of cumulative resistance by recombinations of genetic factors is thus introduced. This type of recombination is in addition to possible multiple factors which may lie at the basis of any one of the three characteristics. The expression of the genetic factors resulting in these three characteristics is frequently found to be modified by various ecological conditions and by other genetic factors. For instance the recent work on the resistance of sorghums to chinch bugs done by Dahms *et al.* (1936, 1940) following the earlier studies by Snelling *et al.* (1937) shows at present the following principal relationships, with further details still being studied. (Fig. 2)

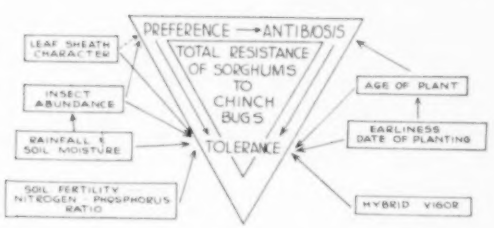


FIG. 2.—Principal interrelations in resistance of sorghums to chinch bug.

The mechanisms lying back of this basic triangle may be analyzed in terms of plant characters and insect behavior or physiology. (Fig. 3). Most of the various

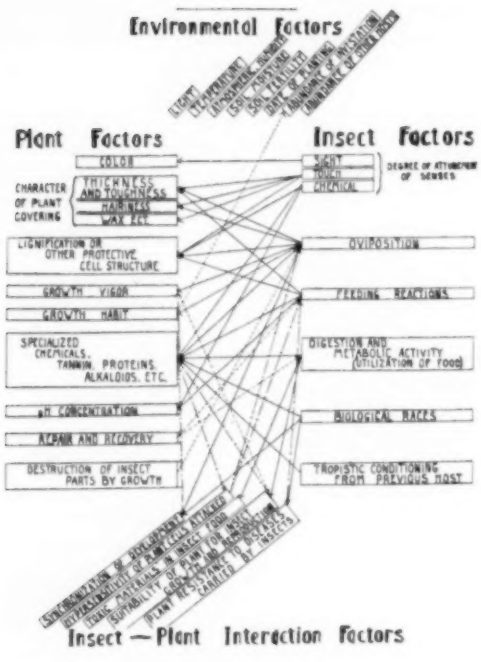


FIG. 3.—Interrelations of Factors in Resistance of Plants to Insects.

items that have been suggested as "cause" of resistance or as being involved in resistance in different cases may be classified as (1) insect factors (2) plant factors and (3) insect-plant interaction factors. Modifying the expression of these factors are various environmental conditions which may act primarily on the insect, the plant, or the insect-plant relationship. Each of the plant or insect mechanisms indicated may be the result of one or more genetic factors. The possibilities of the interpretation of these genetic factors in respect to the cause of resistance has been discussed previously (Painter 1936). It must be remembered that any study of the cause of resistance is a study of how the genes express themselves and that this field of developmental genetics has so far not progressed very rapidly. There is, however, the possibility that a study of resistance mechanisms may contribute important information toward this field.

PERMANENCE OF RESISTANCE.—The second most frequently asked question concerning resistance projects is, "How permanent can we expect insect resistant varieties to be?". Again the information bearing on this question, especially in regard to more recent projects, is rather scanty. In some other respects we have much information. Certain varieties or clones of apples for instance, are known to have remained resistant to the woolly apple aphid for more than a hundred years. This has occurred even though, according to recent information (Hatton *et al.* 1937), the genetic character for resistance has been carried in the heterozygous condition in some of the varieties. Certain grape species are known to have remained resistant to Phylloxera for more than seventy years and under a wide variety of conditions in many countries. The useful permanence of resistance in the control of these two insects is thus older than most other specific control measures or insecticides.

In more recent studies there has been a varying amount of evidence of permanence. Oregon Evergreen sweet corn studied by Collins & Kempton (1917) in 1915 and 1916 was chosen because it was "one of the most worm resistant of the commercial varieties of sweet corn." Twenty years later Poole (1935, 1936) and others in the interim have recorded this variety as still among the older sweet corn varieties which were more resistant to corn earworm. Atlas Sorgo, which was distributed to Kansas farmers in 1928 and first studied for chinch bug resistance in 1925 and 1926, is grown extensively in eastern Kansas and in other areas where chinch bug infestations are sometimes severe. So far as known it has retained its usual degree of resistance to the present time in all comparative tests. The resistance of various winter wheat varieties to hessian fly has been studied at the Missouri station since 1919. In 1933 certain of these winter wheats, notably Illini Chief, which previously had been reported as resistant were reported as susceptible (Haseman *et al.* 1921; Haseman 1933). These same varieties have been studied at the Kansas station over a somewhat longer period of time. There has been some evidence in recent years of a small increase in susceptibility of at least some of the varieties. A widespread change in the proportion of biotypes of hessian fly in the infesting population used is a possible cause although other reasons have not been entirely eliminated.

The question, "How permanent is resistance?", is essentially a problem in experimental evolution, the development of

host relations, rate of mutation, selection, etc. Any answer depends to a considerable extent on the mechanisms of resistance involved and will differ in different cases. Of the three basic characteristics involved in resistance, namely, preference, antibiosis, and tolerance, it will be noticed that these frequently are concerned with physiological characters either in the insect or in the plant or in both. Physiological characters frequently have been considered less stable than morphological ones. Kinsey (1929) has shown that, in the gall wasp genus *Cynips*, physiological characters are fully as stable phylogenetically as morphological ones. A little reflection will call to mind many cases where physiological characters of orders and families of insects are quite as characteristic as are morphological ones and one probably as old, (Brues 1939). Hence there is no reason to consider resistance which depends on physiological characters to be any less permanent than that dependent on morphological characters since both are subject to mutation and the laws of inheritance and natural selection.

Of the three characters mentioned above, preference appears most likely to be affected by temporary changes in insect habits and, with tolerance, to be more frequently affected by ecological conditions. The various biological effects included under the term antibiosis appear to be more stable, to be changed chiefly by mutations which become evident as biological strains of insects or as susceptible strains within a resistant variety. The former must always be taken into consideration as a possible source of variability in resistance, while the latter quickly become evident through a progeny test. If mutant biotypes are already present in the insect population the straining effect of resistant varieties will easily bring them out. This may cause apparent break-down of resistant characters. It is to be noted that similar mutant biotypes have also appeared in chemical control work and are causing difficulties (Webster 1933).

In the case of wheat varieties resistant to hessian fly, for example, the question of how soon a strain of fly might become adapted to a resistant wheat is dependent on at least the following variables:

(1) The original proportion, if any, of the population capable of feeding on the resistant variety.

(2) The genetic relationships of the strain of fly to other strains.

(3) The ecological adaptations of the strain of fly feeding on the resistant wheat.

(4) The number of genetic factors and resistance characters involved in the resistance of wheat.

(5) The purity of the resistant variety as grown on farms.

(6) The proportion of acreage of resistant to susceptible varieties in a given area.

(7) The thoroughness with which other control measures are practiced, especially the plowing under of stubble and volunteer plants. Many of these variables apply equally in similar cases.

Under the most unsatisfactory conditions with respect to permanence of resistance the question resolves itself into one of whether the plant breeder and entomologist shall be able to keep one jump ahead of nature. In the similar field of breeding for resistance of plants to disease, the answer has certainly been in the affirmative. If a resistant variety such as one resistant to the hessian fly prevents, under the most discouraging conditions, only a single general outbreak, everything gained will be worth while, provided only that the resistant variety has been equal or superior in other important characters to those previously grown. The prevention of such a single outbreak of a major insect pest would more than finance research done to date on insect resistance. There is every reason to believe, considering the information at hand, that insect resistance in crop plants will be of greater permanence than this.

These considerations bring up a much more difficult question in which the entomologist must be interested. This is the problem of distinguishing between the effects on insect populations of an insect resistant variety gradually placed in agricultural production from the normal fluctuations in populations resulting from climatic and other factors. To demonstrate fully the value of insect resistance in crop plants, data on this question must be gathered.

SOME FACTS OF BIOLOGICAL SIGNIFICANCE TO BE DERIVED FROM RESISTANCE STUDIES.—Enough facts have been given above and in other papers to indicate

that studies of insect resistance can furnish information of theoretical interest in many fields of entomology and in some fields of botany. This is particularly true of the insect-food relations which are evidently a basic feature of resistance. The importance of food relations in connection with facts in classification and evolution of insects has been established for a long time (Osborn 1908; Brues 1936, 1939). Through a study of insect resistance some of the details in these fields are being filled in.

In connection with the plants, evidence has been secured that genetic factors for insect resistance can be transferred from one species of plant to another. Genes for resistance of wheat to hessian fly have been transmitted from *Triticum durum* by way of Marquillo spring wheat to varieties of winter habit (*Triticum vulgare*) (Painter *et al.* 1940). It has likewise been found possible in the case of Phylloxera to transfer resistance to the insect from one plant species to another (Husman 1930). Such interspecific transfer may also have occurred in nature.

Normally it would be expected that those varieties of crop plants exposed for the longest time to the attacks of a specific insect would be most resistant to that insect and that natural selection would be an important factor in separating out resistant genes. Evidence indicating that this is true is available in the case of corn and grasshoppers (Brunson & Painter 1938) and of corn and chinch bugs (Flint 1921). The same may be also true of corn earworm (Collins & Kempton 1917; Painter & Brunson 1940). In these cases resistant inbreds, or varieties have come largely but not exclusively from plant populations most exposed for the longest time to the attacks of the insect concerned.

In distinct contrast to the cases cited above is the relationship of sorghums to chinch bugs. No insect even resembling the chinch bug is known to occur in Africa or Asia where the sorghums originated; yet when sorghum varieties are brought into the presence of chinch bugs in this country they are found to differ greatly in factors for insect resistance (Snelling *et al.* 1937). Hence differences in resistance had already developed in sorghums before they encountered chinch bugs. There has been evidence from many sources, both mathematical and experimental (Huxley 1940), that the differentiation of species and lower categories may take place in the presence of isolation alone. Here in the case of sorghum and chinch bugs there is found evidence of the origin of physiological characters for resistance in the apparent absence of natural selection. While this fact is of theoretical interest, workers in plant resistance to insects should remember that the presence of the insect resisted may not be necessary for the development of resistance.

While the presence of insect resistance among individuals, varieties, or species of wild plants in nature has rarely been recorded (Painter 1935; Hayes & Johnston 1925; Jones 1936, 1939) there seems to be no reason to believe that resistance relationships found in domesticated plants do not also occur among wild ones. The presence of biotypes of insects differing in host plant relations has been found rather frequently (Thorpe 1930; Huxley 1940) and in nature and is the converse of resistance in this insect-plant relationship. The alternate development of these two sides of the complex must, in nature, have introduced fluctuation in population levels which have been of importance in evolution (Huxley 1940, p. 113). It has frequently been pointed out that the characters which taxonomists use to separate species can hardly have had enough adaptive value for survival through natural selection (Robson & Richards 1936). It is possible that the development of resistance in plants or of biotypes in insects may in some cases have been the isolation factors which allowed such specific characters to be developed.

Aside from these theoretical aspects, research on insect resistance has encouraged investigations of various plant-insect relationships. Information has been obtained on such features as the detailed methods of insect feeding (Painter 1928; Smith & Poos, 1931) a greater knowledge of the method of insect injury to plants (Poos & Johnson 1936; Dieter & Wilson 1940), and edaphic conditions that affect insect resistance (Dahms & Fenton 1940). These have enriched and contributed to the knowledge of insect biology, and it is reasonable to expect further information of this character. Resistant plants may furnish some new tools for the study of the

physiology of phytophagous insects. These are some of the instances in which a knowledge of insect resistance may be of use to workers in other fields.

CONCLUSION.—Herein have been indicated a few of the significant facts related to biology in general which have been gained from a study of insect resistance incrop plants. On the economic side the to stabilize crop production by limiting fluctuations due to insect injury. It has an additional advantage over some control measures such as time of planting to escape hessian fly damage, in that its effectiveness does not depend on regional cooperation, but can be utilized by an individual farmer. In such cases as second generation chinch bugs it permits some

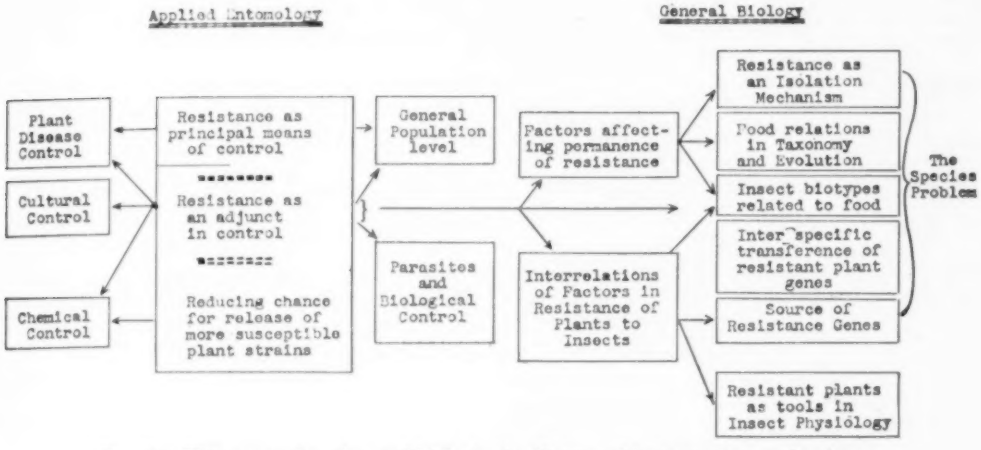

Applied Entomology
General Biology
Plant Disease Control
Cultural Control
Chemical Control
Resistance as principal means of control
Resistance as an adjunct in control
Reducing chance for release of more susceptible plant strains
General Population level
Parasites and Biological Control
Factors affecting permanence of resistance
Interrelations of Factors in Resistance of Plants to Insects
Resistance as an Isolation Mechanism
Food relations in Taxonomy and Evolution
Insect biotypes related to food
Inter-specific transference of resistant plant genes
Source of Resistance Genes
Resistant plants as tools in Insect Physiology
The Species Problem

FIG. 4.—The economic value and biologic significance of insect resistance in plants.

use of resistant varieties shares with the use of insect parasites and predators in insect control, the advantage of a negligible cost to the user. Indeed where resistant genes are incorporated into new and improved varieties the commercial use of these resistant varieties may pay additional profit because of the presence of improvements in addition to insect resistance. The use of a resistant variety, should it become widespread, might tend control of an insect pest at a time when no other means of control yet known is practical. Above all it may, where necessary, be combined effectively with most other control measures.

The accompanying diagram (Fig. 4) summarizes the various relationships, discussed in this paper, between a study of resistance to insects in plants and the study of applied entomology and general biology.—1-27-41.

LITERATURE CITED

Bradley, W. G., and K. T. Arbuthnot. 1938. The relation of host physiology to development of the braconid parasite *Chelonus annulipes* Wesmael. Ann. Ent. Soc. Amer. **31**: 359–65.

Brues, C. T. 1936. Aberrant feeding behavior among insects and its bearing on the development of specialized food habits. Quart. Rev. Biol. **11**: 305–19.

Brues, C. T. 1939. Food, Drink and Evolution. Science **90**: 145–49.

Brunson, A. M., and R. H. Painter. 1938. Differential feeding of grasshoppers on corn and sorghums. Jour. Amer. Soc. Agron. **30**: 334–46.

Collins, G. H., and J. H. Kempton. 1917. Breeding sweet corn resistant to the corn ear worm. Jour. Agr. Res. **11**: 549–72.

Compton, C. C., and C. W. Kearns. 1937. Improved control of red spider on greenhouse crops with sulfur and cyclohexylamine derivatives. JOUR. ECON. ENT. **20**: 51–521.

Dahms, R. G., R. O. Snelling and F. A. Fenton. 1936. Effect of several varieties of sorghum and other host plants on biology of the chinch bug. JOUR. ECON. ENT. **29**: 1147–53.

Dahms, R. G., and F. A. Fenton. 1940. The effect of fertilizers on chinch bug resistance in sorghums. JOUR. ECON. ENT. **33**: 688–92.

Dahms, R. G., and R. H. Painter. 1940. Rate of reproduction of the pea aphid on different alfalfa plants. JOUR. ECON. ENT. **33**: 482–5.

Dieter, C. E., and H. F. Wilson. 1939. Injury to pea vines caused by the feeding of the pea aphid. Jour. Agri. Res. **59**: 805–14.

Dunnam, E. W. 1936. Pilosity of the cotton plant in relation to adherence of dusted calcium arsenate. JOUR. ECON. ENT. **29:** 1085–7.
Eichmann, R. D., and R. L. Webster. 1940. The influence of alfalfa on the abundance of the pea aphid on peas grown for canning in southeastern Washington. Wash. Agr. Expt. Sta. Bul. 389.
Flanders, S. E. 1936. Host influence on the prolificacy and size of *Trichogramma*. Pan. Pac. Ent. **11:** 175–7.
Flanders, S. E. 1939. Environmental control of sex in hymenopterous insects. Ent. Soc. Amer. **32:** 11–26.
Flanders, S. E. 1940. Environmental resistance to the establishment of parasitic hymenoptera. Ann. Ent. Soc. Amer. **33:** 245–53.
Flint, W. P. 1921. Chinch bug resistance shown by certain varieties of corn. JOUR. ECON. ENT. **14:** 83–5.
Flint, W. P., and W. L. Burlison. 1920. Crop rotations to starve chinch bugs. Ill. Agr. Ext. Circ. **39.**
Haseman, L. 1933. Hessian fly resistant varieties of wheat. Mo. Agr. Expt. Sta. Bul. **328:** 129.
Haseman, L., K. C. Sullivan and S. R. McLane. 1921. Entomological Investigations, 1919–1920. Mo. Agr. Expt. Sta. Bul. **179:** 26–30.
Hatton, R. G., W. S. Rogers, R. M. Greenslade, M. B. Crane, A. M. Massee, H. M. Tydeman and W. A. Roach. 1937. The problems raised by the wooly aphis of the apple—A case for team research. Ann. App. Biol. **24:** 169–210.
Hayes, Wm. P., and C. O. Johnston. 1925. The reaction of certain grasses to chinch bug attack. Jour. Agr. Res. **31:** 575–83.
Holbert, J. R., W. P. Flint, J. H. Bigger and G. H. Dungan. 1935. Resistance and susceptibility of corn strains to second brood chinch bugs. Iowa State Col. Jour. Sci. **9:** 413–16.
Hollowell, E. A., J. Monteith, Jr. and W. P. Flint. 1927. Leafhopper injury to clover. Phytopath. **17:** 399–404.
Howard, L. O. 1930. A history of applied entomology. Smith. Misc. Coll. **34.**
Husmann, George C. 1930. Testing phylloxera—resistant grape stocks in the vinifera regions of the United States. U.S.D.A. Tech. Bul. **146.**
Huxley, J. 1940. The New Systematics. Oxford Univ. Press. Oxford, England.
Isely, D. 1935. Relation of Hosts to abundance of cotton bollworm. Ark. Sta. Bul. **320.**
Jewett, H. H. 1932. The resistance of certain red clovers and alfalfas to leafhopper injury. Ky. Sta. Bul. **329:** 155–72.
Johnson, H. W., and E. A. Hollowell. 1935. Pubescent and glabrous characters of soybeans as related to resistance to injury by the potato leaf hopper. Jour. Agr. Res. **51:** 371–81.
Jones, Elmer T. 1936. Hordeum grasses as hosts of the hessian fly. JOUR. ECON. ENT. **29:** 704–10.
Jones, Elmer T. 1937. Differential resistance to chinch bug attack in certain strains of wheat. Trans. Kans. Acad. Sci. **40:** 135–42.
Jones, Elmer T. 1939. Grasses of the tribe Hordeae as hosts of the hessian fly. JOUR. ECON. ENT. **32:** 505–10.
Kinsey, A. C. 1930. The gall wasp genus *Cynips*. Indiana Univ. Studies, Vol. XVI.
Osborn, Herbert. 1908. The habits of insects as a factor in classification. Ann. Ent. Soc. Amer. **1:** 70–84.
Painter, R. H. 1928. Notes on the injury to plant cells by chinch bug feeding. Ann. Ent. Soc. Amer. **21:** 232–42.
Painter, R. H. 1935. The biology of some dipterous gall makers from Texas. Kansas, Ent. Soc. Jour. **8:** 81–97.
Painter, R. H. 1936. The food of insects and its relation to resistance of plants to insect attack. Amer. Nat., **70:** 547–66.
Painter, R. H., and Arthur M. Brunson. 1940. Differential injury within varieties, inbred lines, and hybrids caused by the corn ear worm (*Heliothis armigera* (Hbn.)) Jour. Agr. Res. **61:** 81–100.
Painter, R. H., and C. O. Grandfield. 1935. Preliminary report on resistance of alfalfa varieties to pea aphids (*Illinoia pisi* (Kalt.)). Jour. Amer. Soc. Agron. **8:** 671–4.
Painter, R. H., Elmer T. Jones, C. O. Johnston and J. H. Parker. 1940. Transference of hessian fly resistance and other characteristics of Marquillo spring wheat to winter wheat. Kan. Agri. Sta. Tech. Bul. **49.**
Phillips, A. M., and M. C. Swingle. 1940. Rearing of mosquito larvae and effect of diet on their resistance to rotenone and nicotine. JOUR. ECON. ENT. **33:** 172–6.
Poole, C. F. 1935. Corn ear worm resistance in maize varieties at Davis, California, 1935. Amer. Soc. Hort. Sci. Proc. (1934) **32:** 453–7.
Poole, C. F. 1936. New sweet corns resistant to earworm. Amer. Soc. Hort. Sci. Proc. **33:** 496–501.
Poos, F. W., and H. W. Johnson. 1936. Injury to alfalfa and red clover by the potato leafhopper. JOUR. ECON. ENT. **29:** 325–31.
Poos, F. W., and F. F. Smith. 1931. A comparison of oviposition and nymphal development of *Empoasca fabae* (Harris) on different host plants. JOUR. ECON. ENT. **24:** 361–71.
Robson, C. C., and O. W. Richards. 1936. The Variation of Animals in Nature. London. Longmans, Green.
Sanderson, M. W.: 1939. Crop replacement in relation to grasshopper abundance. JOUR. ECON. ENT. **23:** 484–6.
Schwartze, C. D., and G. A. Huber. 1939. Further data on breeding mosaic-escaping raspberries. Phytopathology **29:** 647–48.
Seamans, H. L., and Ellis McMillan. 1935. The effect of food plants on the development of the pale western cutworm (*Agrotis orthogonia* Morr.) JOUR. ECON. ENT. **28:** 421–5.

Smith, Floyd F., and F. W. Poos. 1931. The feeding habits of some leafhoppers of the genus *Empoasca*. Jour. Agr. Res. **43**: 267–85.
Snelling, R. O., R. H. Painter, J. H. Parker and W. M. Osborn. 1937. Resistance of sorghums to the chinch bug. U. S. Dept. Agr. Tech. Bul. **585**.
Swingle, M. C. 1939. The effect of previous diet on the toxic action of lead arsenate to leaf-feeding insects. JOUR. ECON. ENT. **32**: 884.
Thorpe, W. H. 1930. Biological races in insects and allied groups. Biol. Rev. **5**: 177–212.
Webster, R. L. 1933. Insect tolerance. JOUR. ECON. ENT. **26**: 1016–21.

Experiments with an Ambrosia Beetle, *Xylosandrus germanus* (Blfd.)

W. D. BUCHANAN,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In a previous study (Buchanan 1940) the ambrosia beetle *Xylosandrus germanus* (Blfd.) was shown to transmit the Dutch elm disease fungus, *Ceratostomella ulmi* Buisman, to nursery elm trees under controlled conditions. The beetles used were artificially contaminated with *C. ulmi* because there were none available from sources in which the fungus was known to occur. In fact the only beetles that have been available for experimental purposes were reared from field-infested stumps, exposed roots, and fallen branches that were found more or less by accident. In order that a dependable supply of these beetles would be accessible for transmission and biological studies, it was considered advisable to develop a technique for infesting with *X. germanus* in the laboratory sections from diseased as well as non-diseased trees.

In the summer of 1940, adults of *Xylosandrus germanus* were enclosed in 3-gallon battery jars containing sections from recently felled trees. Some jars contained sections stripped of bark, some held sections with the bark intact, and others held sections of both types. The 149 sections used ranged in size from about 1.5 to 4 inches in diameter and were 14 inches long. They were placed upright on wet sand and the top of each jar was covered with muslin, over which glass was placed. Within a few hours after being liberated into the jars, many of the beetles began to bore into the ends and sides of the sections stripped of bark, and approximately 2 months later the new brood began to emerge in large numbers from the sections. The beetles frequently entered the ends of sections bearing bark but they seldom bored through the bark to the sapwood, and they did not oviposit in these sections.

After it was found that *Xylosandrus germanus* in battery jars would oviposit in sections of elm stripped of bark, tests were made to determine whether or not the beetles would do the same on living trees the bark of which had been injured or removed. Four adjacent squares, about 8 inches on a side, were marked on the trunks of each of 13 standing elms in two localities where *X. germanus* was known to be more or less abundant. In one square the bark was completely removed, in another it was shaved off, leaving a thin layer of inner bark, in the third square the bark was bruised, and in the fourth it was undisturbed. *X. germanus* began almost immediately to bore into the debarked and shaved squares and continued to do so for about 2 weeks, but no attack was ever noted in the bruised or undisturbed areas. The beetles that bored into the trees abandoned them without ovipositing.

When *Xylosandrus germanus* was found to attack tree areas shaved or stripped of bark, the experiment was extended in an effort to obtain more information on the possible relation of this insect to the spread of the Dutch elm disease in the field. An area of bark about 8 inches wide and 20 inches long was shaved from the trunk of each of 110 trees distributed in 3 localities. No attacks were found in 20 of the trees, but 1,244 attacks were found in the shaved areas of the other 90. The number of injuries in these ranged from 1 to 106, with an average of 13.8. No eggs were laid in the trees, nor did any of the trees develop external symptoms of the Dutch elm disease. It is probable that none of the beetles which attacked the trees were contaminated with the disease,

[1] The writer is indebted to Curtis May, of the Bureau of Plant Industry, U. S. Department of Agriculture, for his interest, helpful suggestions, and assistance in identifying the fungi mentioned in this paper.

since no *Ceratostomella ulmi* was isolated in cultures made from 81 adults or from wood tissue surrounding 178 entrance holes in 36 trees.

As a check on the foregoing experiment, tests were conducted to determine whether or not external symptoms of the Dutch elm disease would develop in field trees that were attacked by *Xylosandrus germanus* known to be contaminated with *Ceratostomella ulmi*, and whether or not the beetles would oviposit in the trees if external symptoms did develop.

On July 1 an area of bark 8 inches long and extending about one-third around each of 13 trees was so shaved that only a thin layer was left. The trees ranged from 4 to 8 inches in diameter and were approximately 40 feet high. A muslin cage was attached to the trunk of each of the 13 trees so that it enclosed the shaved as well as an unshaved area. Twenty-five *Xylosandrus germanus* beetles that had become contaminated with *C. ulmi* by walking over a culture of the fungus were confined in each cage. By September 4 external symptoms of the Dutch elm disease had developed in every tree, and *C. ulmi* was isolated from twigs taken from the crowns. Even though it was not possible to enclose the trees so that there was no possible attack from bark beetles, such as *Hylurgopinus rufipes* (Eich.) and *Scolytus multistriatus* (Marsh.), the writer feels confident that the infection started from the attack of the contaminated *X. germanus*. This is indicated by the absence of external symptoms of the disease in adjacent elms; the lack of any trunk or twig-crotch injuries in four trees that were examined minutely after being felled; the presence of a band of color on every tree, extending up the trunk from the shaved area into which the beetles bored; and the lack of color in other parts of the trunk 3 weeks after the beetles were caged on them. No eggs were laid in the trees by *X. germanus*.

At the time the above-mentioned work was being conducted, R. P. True, of the Bureau of Plant Industry, Department of Agriculture, noted that beetles were attacking elm trees which he had injected with dichlorophenol dissolved in 50 per cent ethyl alcohol. The beetles were identified as specimens of *Xylosandrus germanus*.

With these observations in mind the present writer injected 30 other trees with 100 to 300 cubic centimeters of 50 per cent ethyl alcohol per inch of diameter. The trees ranged from 1 to 3 inches in diameter at breast height. The method used to inject the alcohol was similar to that described by Banfield.[2] The alcohol was held in a metal collar that encircled the trunk. Then a broken ring of cuts was made in the bark and sapwood of the tree with a chisel one eighth inch wide, the blade of which had been submerged in the alcohol. *X. germanus* beetles were enclosed in battery jars containing sections from alcohol-injected trees and sections from noninjected trees but stripped of bark. In every jar the sections from the alcohol-injected trees were heavily attacked, but the debarked sections from normal trees showed little or no beetle injury.

Xylosandrus germanus larvae removed from their brood chambers in elm and red pine transformed to adult beetles after feeding for over a month on one of the following fungi: *Ceratostomella pluriannulata* Hedge.,[3] taken from perithecia surrounding *X. germanus* larvae in brood chambers in red pine, *Pinus resinosa* Aiton; *C. ulmi* taken from elm but not associated with *X. germanus; Pestalozzia sp.*, separated from a mixture of fungi and yellow bacteria growing in an agar plate after an adult beetle from elm had walked over the medium; and one unidentified fungus, transferred from the walls of a brood chamber of *X. germanus* in elm. Larval mortality was high in all attempts to rear them on fungi outside their brood chambers.

Xylosandrus germanus eggs from a brood chamber in elm were placed on a pure culture of *Pestalozzia* sp. in a petri dish. Six weeks later an adult beetle developed from one of the larvae that hatched and fed on that fungus.

Virgin females, and a few females that may have been fertilized, were placed on cultures of the fungi mentioned above. They made tunnels in the agar, but no eggs were laid in the tunnels. Virgin females did not oviposit in tunnels they made in sections of elm from which the bark had been removed.

Yellow bacteria have grown along the courses followed by larvae and adults that

[2] In press.
[3] Identified by Ross W. Davidson, of the Bureau of Plant Industry.

have moved over culture media composed of potato sucrose agar. Larvae appear to feed on the bacteria and live until they are engulfed and apparently killed by drowning.

SUMMARY.—The ambrosia beetle *Xylosandrus germanus* (Blfd.) was reared in the laboratory from debarked trunk sections taken from elm trees in the field. The beetles seldom entered wood on which the bark was left intact. When the outer bark or both the outer and inner bark were removed from small areas on the trunks of living trees in the field, the beetles attacked these areas but did not oviposit in them. Thirteen elm trees were thus exposed to infestation by beetles that had been artificially contaminated with *Ceratostomella ulmi*. All these trees developed external symptoms of the Dutch elm disease, and the fungus was isolated from the crown of each tree.

The injection of ethyl alcohol into living trees was found to render them attractive to *Xylosandrus germanus* beetles.

Larvae that were removed from brood chambers in elm or red pine changed to adult beetles after they had been fed for over a month on one of the following fungi: *Ceratostomella ulmi*, *C. pluriannulata*, *Pestalozzia sp.*, and one unidentified fungus.—1-26-41.

LITERATURE CITED

Buchanan, W. D. 1940. Ambrosia beetle *Xylosandrus germanus* transmits Dutch elm disease under controlled conditions. JOUR. ECON. ENT. 33(5): 819–20.

Banfield, W. M. Distribution by the sap stream of the spores of three fungi which induce vascular wilt diseases of elm. Jour. Agr. Res. (*in press.*)

Studies of Elm Insects Associated with Dutch Elm Disease Fungus

C. W. COLLINS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The research projects on the relationship of insects to the Dutch elm disease, *Ceratostomella ulmi* Buisman, mentioned in this paper include some of the more important activities engaged in at the Morristown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine. The recent results of some of them are described briefly, since it is expected that more detailed information will be presented by various workers in future publications.

Experiments were conducted during the years 1936–39 in six locations in New Jersey to ascertain what species of insects were carrying *Ceratostomella ulmi* and from what proportion of the population of each the organism could be isolated. Insects attracted to felled healthy elm trees were collected, mostly on alternate days during the active season, and later cultured. All species of insects attracted to elm were collected and cultured during 1936, but only *Scolytus multistriatus* (Marsh.) and *Hylurgopinus rufipes* (Eich.) were included in the 1937, 1938, and 1939 collections. T. H. Jones, of the Bureau of Entomology and Plant Quarantine, and C. S. Moses, of the Bureau of Plant Industry, report that *C. ulmi* was obtained from 6.9, 5.8, 7.7, and 5.71 per cent of the *S. multistriatus* and from 4.3, 2.4, 3.3, and 0.7 per cent of the *H. rufipes* cultured, in 1936, 1937, 1938, and 1939, respectively.[1] Many more of the former species than of the latter were taken during these years, and the percentage of contaminated *S. multistriatus* was more than double that of contaminated *H. rufipes* during each year except 1936.

Of numerous other species taken in 1936 only small percentages of the following four were contaminated by the fungus: *Xylosandrus germanus* (Blfd.), *Xylobiops basilare* Say, *Magdalis armicollis* (Say), and *Conotrachelus anaglypticus* (Say).

Scolytus multistriatis is by far the most important insect carrier of *Ceratostomella ulmi* in the major area affected by the disease. Laboratory experiments and field observations have shown that the adults emerging from infected logs or parts of trees may carry the fungus and introduce it into living trees by means of crotch feeding, or by boring into the trunk or limbs of trees when contacting the xylem.

[1] Unpublished manuscript.

The former habit is noted commonly in the field, but the latter also prevails at a time when the sap is flowing freely and the trees are susceptible to infection by the fungus.

In an effort to obtain more data on the habits of the beetles in boring into the trunk and limbs, R. T. Webber during the period July 8 to 18, 1938, felled, stripped of bark, and minutely examined 18 normal elms $3\frac{1}{4}$ to 9 inches d.b.h. The trees were from an area near Towaco, N. J., which was believed to be heavily infested with *Hylurgopinus rufipes*, but *Scolytus multistriatus* also occurred in the vicinity. Counts were made of the number of borings which extended to the xylem. When feeding or hibernating tunnels were found in the outer bark the injury was considered to have been caused by *H. rufipes* and when these tunnels were absent the injury was considered to have been caused by *S. multistriatus*. A total of 55 tunnels contacting the xylem, and of sufficient depth to effect inoculation, was evident in 13 of the 18 trees examined. Of these, 18 were classified as having been made by *H. rufipes* and 15 by *S. multistriatus*, and 22 were unclassified.

On June 18 and 19, 1940, a similar examination of 13 small trees was made in Chatham, N. J. A total of 14,400 adults of *Scolytus multistriatus* reared at the laboratory had been liberated near the trees examined. Forty-two xylem contacts ranging from 1 to 16 per tree were found. Twenty-nine of these were classified as having been made by *S. multistriatus*, the adults being present in the entrance burrows in four cases, 1 was made by *Hylurgopinus rufipes*, and 12 were unclassified. Other data have been accumulated which substantiate those presented above.

Laboratory experiments and field observations have shown that *Hylurgopinus rufipes* plays a rather important role as a carrier of *Ceratostomella ulmi*, especially in areas where the fungus has become established and where *Scolytus multistriatus* does not occur. R. T. Webber found that overwintering adults contaminated with the organism do, to a limited degree, inoculate normal living elms. In October 1939 artificially contaminated *H. rufipes* adults were confined to lower trunk sections of 11 trees by the use of cloth sleeves. Only one tree became infected with the fungus and the remaining trees showed no external symptoms of the disease. Elm trees cut and stripped of their bark in the spring sometimes show numerous entrance holes made through the bark and evidence that the beetles had contacted the xylem. Much of this boring into living trees takes place, in northern New Jersey, in April and early May, which is prior to the maturation of the new vessels in the elm. Such contacts with the xylem by some of the overwintering adults are for the most part ineffective in inoculating the trees, since the insects do not appear to contact the newly formed spring vessels. A higher percentage of inoculation from contaminated adults is believed to come from beetles maturing from overwintering larvae and emerging later in the spring after the spring vessels are formed and functioning, or after sap has begun to move in the trees.

Scolytus sulcatus Lec. breeds in apple, which is probably its preferred host. It also breeds in elm, but field records do not indicate that it is very common on this host plant. Buchanan (1940a) showed it to be a transmitter of *Ceratostomella ulmi* under controlled conditions. He demonstrated that adults issuing from infected and infested elm inoculated nursery elms and apple trees. Foliar symptoms developed in the elms but not in the apple trees. In 1940, with the cooperation of C. S. Moses, Buchanan recovered the fungus from beetles breeding in apple but not from their wood galleries. The fungus was brought into the apple logs by adults emerging from infested and infected elm or apple. From our present knowledge of the habits and rare occurrence of this insect in elm in northern New Jersey and nearby sections, it is not considered of great importance in the eradication project against the Dutch elm disease.

An ambrosia beetle, *Xylosandrus germanus* (Blfd.), is commonly found boring into injured portions of elm trees, cut elms, and stumps. Since field collections of adults for culture have shown that these beetles do carry the fungus occasionally, experiments have been conducted to ascertain to what extent and under what conditions *X. germanus* may act as a carrier of *Ceratostomella ulmi* in the field. Buchanan (1940b), in working with artificially contaminated beetles confined on nursery trees planted in tubs, which in turn were enclosed in large screen cages,

succeeded in getting infection in some trees in 1939. He carried this experiment further in July 1940 by confining contaminated beetles on portions of the trunk of 13 normal elms growing on laboratory property. The outer bark was shaved from a strip about 12 inches wide extending about one-third the distance around the lower trunk. Artificially contaminated adults were confined by means of cloth sleeves to that section of the trunk. They readily entered the shaved surfaces and in no case attempted to bore into the unshaved portions. In less than 3 weeks wilting of the foliage began to show on 1 of the trees. A few days later foliar symptoms had developed in all the remaining trees. C. S. Moses, in culturing twig samples, was able to recover the fungus from the tops of all the trees.

These results would indicate that, since this insect is sometimes abundant in the field, it might act as a carrier of the fungus to scarred or otherwise injured elms when breeding in dead and diseased elm nearby. Further work is needed to determine to what extent this insect may be a factor in spreading the disease organism under such conditions.

Ceratostomella ulmi has been isolated from adults of the elm borer, *Saperda tridentata* Oliv., that emerged from diseased wood in cages; also one contaminated adult has been taken in the field. Laboratory experiments have shown this insect to be an ineffective transmitter of the fungus. Contaminated adults transmitted the disease organism by their feeding on the midribs and veins of the leaves or the succulent growth, but such transmission invariably resulted in extremely localized infection. The maximum distance from the point of infection and the point of recovery of the organism was 10 centimeters. No foliar symptoms developed.

In field practices of eradication and control of the disease many natural elm stumps have been left in areas where there were concentrations of trees of low value. R. T. Webber has observed that such stumps are attractive to *Saperda tridentata* and ambrosia beetles, and to some other species associated with the Dutch elm disease. There are also records of considerable attack by *S. tridentata* and ambrosia beetles on stumps treated with copper sulfate.

To ascertain whether a possible build-up of *Ceratostomella ulmi* could occur in untreated or natural stumps, artificially contaminated adults of *Saperda tridentata* were caged on a large series of stumps in 1938. The results were unsatisfactory, since the stumps were too green for beetle reproduction. The experiment was repeated in 1939 with success, so far as reproduction was concerned. One hundred and thirty-two adults which emerged from 27 caged stumps in 1940 were cultured by C. S. Moses with negative results. This fact, together with information that the female in ovipositing does not usually insert the eggs deeper than the inner bark, indicates that this species is not likely to be responsible for the building up of reservoirs of the fungus in dead wood.

During the seasons of 1939 and 1940 elm-trap log piles were put out in certain locations in northern New Jersey to attract bark beetles for later destruction with the logs, and to obtain data on the relative bark beetle populations from year to year. The Dutch elm disease control unit of this Bureau distributed the piles and collected them after about 5 or 6 weeks. Each pile contained 25 to 30 logs and the logs were about 6 feet long. The piles were placed in the same locations each year. The basal tiers of the piles were laid in pairs, whereas the upper tiers consisted of solid rows of logs arranged in criss-cross fashion. D. E. Parker and T. H. Jones, of the Morristown, N. J., laboratory, arranged for uniform sampling of the piles for bark beetle population during the 2 years. One hundred and twenty piles were sampled in 1939 and 115 in 1940. There were on an average 7.89 *Scolytus multistriatus* galleries per square foot of bark in 1939 and 3.95 in 1940 and 9.50 *Hylurgopinus rufipes* galleries per square foot in 1939 and 6.02 in 1940. Adults of *H. rufipes* might have been, and probably were, hibernating in the logs when they were put out.

The fact that the number of *Scolytus multistriatus* galleries per square foot of bark for each location was less in 1940 than in 1939 and the average number for all locations was about one-half as great would indicate that populations of this species were smaller in 1940.

General observations in the field, coupled with the fact that the field sani-

tation program more effectively reduces elm bark beetle breeding material, agree with the downward trend of bark beetle population as indicated by the trap log piles.

Experiments have been under way to find an effective contact insecticide for elm wood infested with bark beetles as well as a repellent spray for green logs likely to become infested. Of the many mixtures tested a spray, developed by R. R. Whitten, consisting of four parts by volume of water and one part of orthodichlorobenzene, plus an emulsifier, has given excellent results in killing eggs, larvae, and pupae of both *Scolytus multistriatus* and *Hylurgopinus rufipes*.

Another spray mixture consisting of four parts of light fuel oil and one part of orthodichlorobenzene, when applied to freshly cut elm logs in May, repelled attack by *Scolytus multistriatus* and *Hylurgopinus rufipes* for the remainder of that season. Untreated elm logs cut at the same time and exposed for the same period in the same locations were heavily attacked by both species.

The approximate cost per gallon of these sprays is 20 cents for the oil-orthodichlorobenzene mixture and 18 cents for the orthodichlorobenzene-water emulsion. Although there is but little difference in material costs, the principal advantage of the emulsion is that it eliminates the fire hazard of the fuel oil and the extra weight to be transported into the field. Water can usually be found on location. Satisfactory coverage was obtained with 3 gallons of the spray to 1 cord of small-diameter logs.

In connection with Dutch elm disease eradication it sometimes becomes necessary to eliminate elms from certain areas to lessen the number of scoutings for foliar symptoms of the disease and to reduce bark beetle breeding. The laboratory at Morristown has conducted field tests over a period of years in attempts to find an economical method of introducing chemical solutions into living elm trees to kill them, prevent sprouting and bark beetle breeding. Of the many chemicals tested the following have been the most effective: Sodium arsenite at a dosage as low as 0.5 gram per inch diameter (breast high); copper chloride or copper nitrate at 15 grams; ammonium bifluoride at 30 grams, and copper sulfate or zinc chloride at 60 grams. All these chemicals have been applied in a water solution. The method of application is by a chisel-cut girdle and watertight collar (Lantz 1938). The cost of treating an elm tree 10 inches in diameter is approximately 50 cents, which includes labor and materials.—1-26-41.

LITERATURE CITED

Buchanan, W. D. 1940a. *Scolytus sulcatus* Lec. transmits Dutch elm disease fungus under controlled conditions. JOUR. ECON. ENT. 33(2): 250–1.

Buchanan, W. D. 1940b. Ambrosia beetle, *Xylosandrus germanus*, transmits Dutch elm disease under controlled conditions. JOUR. ECON. ENT. 33(5): 819–20.

Lantz, A. E. 1938. An efficient method for introducing liquid chemicals into living trees. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-434.

INSECT FOOD OF BULLOCK ORIOLE

Icterus bullocki bullocki (Swainson). Two bullock orioles collected in Utah were of particular interest because of the large number of aphids contained in their stomachs. One, collected in an irrigated wheat field at Newton, June 10, 1940, contained an estimated 2,310 aphids, including at least 350 *Macrosiphum granarium* (Kirby), 135 *Rhopalosiphum prunifolii* (Fitch), 5 *Toxoptera graminum* (Rondini), and 20 *Macrosiphum pisi* (Kalt.). Also included were 1 beetle and 5 Collembola.

The second stomach, of a juvenile specimen collected at Randlett, June 6, 1940, contained 149 aphids including 8 *Brevicoryne brassicae* (L.), 12 *Macrosiphum pisi* (Kalt.), 3 *Aphis maidis* Fitch, and 6 sage aphids, *Macrosiphum coweni* (Hunter). Other contents were 2 corn earworms, 2 cutworms, 1 *Euchistus variolarius* (P.-B.) and 6 other Pentatomidae, 2 weevils and 4 other Coleoptera, 1 grasshopper head and numerous insect fragments.

A third such oriole, also collected near Newton on June 10, among wheat, contained 1 grasshopper nymph, 2 lepidopterous larvae, 2 *Lygus elisus* Van. D., 1 *Nysius ericae* (Schill.) and 1 Scarabaeid beetle — 3-1-41.

G. F. KNOWLTON, *Utah Agricultural Experiment Station, Logan.*

Life History Studies of *Neodiprion americanum* (Leach).[1]

L. A. Hetrick, *Field Laboratory, Virginia Agr. Expt. Sta., West Point*

In the autumn of 1938 the author's attention was directed to an area where pine trees had been defoliated during May of that year. These trees were again defoliated in May of the two following years. Increment cores from dominant pines in the infested area showed that some of the trees had failed to make normal growth since 1936. It is not unlikely that the sawfly infestation had existed in this area a year or more prior to becoming sufficiently serious to cause retarded growth of the trees (Figs. 1 and 2).

Reared specimens of larvae and adults of this sawfly were submitted to the United States National Museum for identification, and the species was determined as *Neodiprion americanum* (Leach) by the late Miss Grace Sandhouse. This species was not contained in the museum reference collection. Leach's type specimens, labeled "Georgia, U.S.A.," are in the British Museum.

Description.—The pale yellow eggs of this sawfly are inserted into the sides of the pine needles, a needle frequently containing six or eight eggs laid in a row at intervals of 5 to 10 mm. (Fig. 3).

Young larvae are uniformly pale green with dark heads. Heads of older larvae are

Fig. 1.—Loblolly pines defoliated by *Neodiprion americanum* during May, 1940.

dark brown; their bodies are marked with black spots above the spiracles and have two longitudinal dark bands running the length of the body along the back. Fully grown larvae are 20 to 25 mm. in length.

Prepupae are characterized by their pale heads with dark eye spots. The spots above the spiracles appear as lateral lines, and the two longitudinal lines on the back are narrow and not very prominent.

Fig. 2.—Top of loblolly pine defoliated by *Neodiprion americanum*. Note the developing whorls of new growth which have not been attacked.

The exarate pupae within their bronze-colored silken cocoons are pale green with purple eyes. Male pupae are 7 to 8 mm. in length and female pupae 8 to 10 mm.

Adult females are uniformly straw-colored except for their black serrate antennae, black thoracic markings, and dusky wings. The body is 8 to 10 mm. long.

Except for the straw-colored legs and venter of the abdomen, the adult male is uniformly black with black bipectinate antennae and dusky wings. The body length is 7 to 8 mm. (Fig. 4).

Life History.—Adults of *Neodiprion americanum* emerge from the soil about the middle of October. Oviposition begins immediately; the average number of eggs per female is 106. Terminals at the top of a tree 20 to 30 feet tall are preferred for oviposition. The favorite host tree is the loblolly pine, *Pinus taeda*. The shortleaf pine, *P. echinata*, is less common in eastern Virginia, but where it occurs with *P. taeda* it also is infested. Although some oviposition and larval feeding has been observed on Virginia scrub pine, *P. virginiana*, this tree is usually not attacked by the insects.

The eggs winter in the needles. By spring there is a halo of dead brown needle

[1] Hymenoptera; Diprionidae.

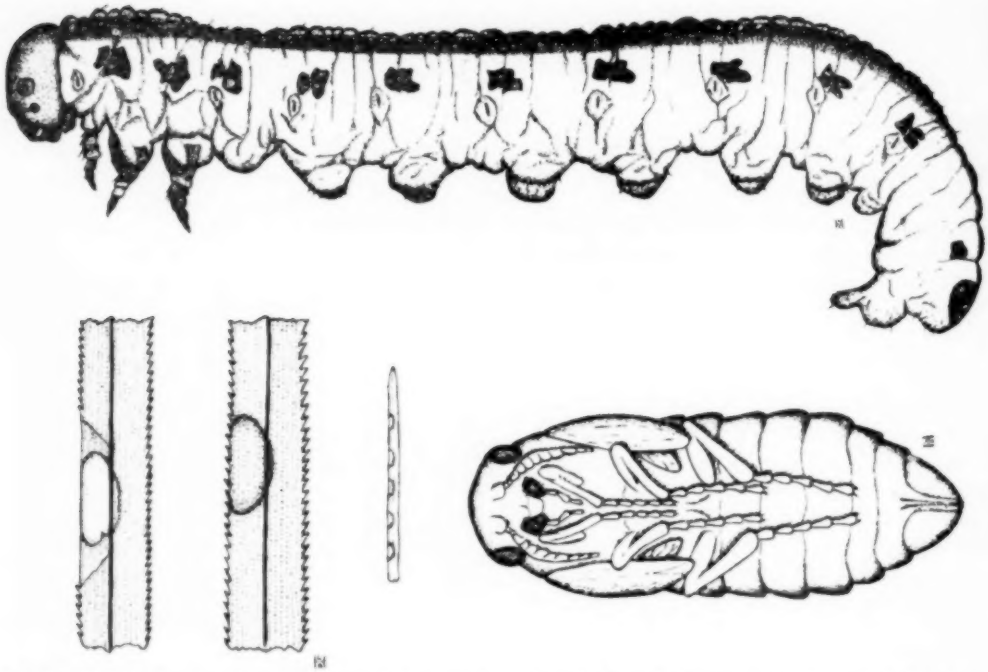


FIG. 3.—*Neodiprion americanum;* above, full grown larva (length, female 25 mm, male 20 mm.); below, eggs in pine needles and pupa of female removed from cocoon. (Length of pupa, female 8–10 mm., male 7–8 mm.)

tissue around each egg. Hatching begins late in April or early in May, depending upon the season. The hatching of the eggs is closely correlated in time with the shedding of pollen from the staminate cones of the loblolly pine. Larval feeding is completed in about 30 days. Male larvae moult four times and the female larvae five times. Briefly the larval feeding may be summarized as follows: first instar, 7 days; second instar, 5 days; third instar, 3 days; fourth instar, 6 days (male larvae transform to prepupae at the end of this instar and enter the soil to spin cocoons); fifth instar (female only), 8 days.

By early June most of the prepupae have entered the soil where they spin cocoons several inches below the surface. Pupation takes place within the cocoons late in September. Transformation to adults takes place about two weeks later. The adult sawflies remain within their cocoons about one week prior to emergence. However, not all of the prepupae transform to adults during the first season; some remain as prepupae until September of the following year. No evidence of any carry-over of prepupae into the third season has been found. There is only one generation each year.

SOIL POPULATION STUDIES.—During the autumns of 1939 and 1940, samples of soil from infested areas were examined for sawfly cocoons. The unit sample was a square foot of soil to an approximate depth of 4 inches. The soil was sifted through a screen made of 8-mesh hardware cloth. It was found that, on the average, there were more than 6 cocoons per square foot in the infested areas, which would be approximately 266,000 cocoons per acre. Approximately 50 per cent of the cocoons examined were parasitized by insects, and another 10 per cent were affected by diseases. Approximately 18 per cent of the cocoons contained prepupae that would have carried over into the following year. However, it is not likely that all of the prepupae that carry over into the second season emerge as adults, since diseases, no doubt, would kill many of them in their cocoons.

NATURAL CONTROL FACTORS.—Late in May 1939 many of the full-grown larvae of *Neodiprion americanum* died in the field and in the insectary. The limp, dead larvae took on a dark brown color. Although the body content had been transformed to a dark brown fluid mass, the integument remained unbroken. Dead

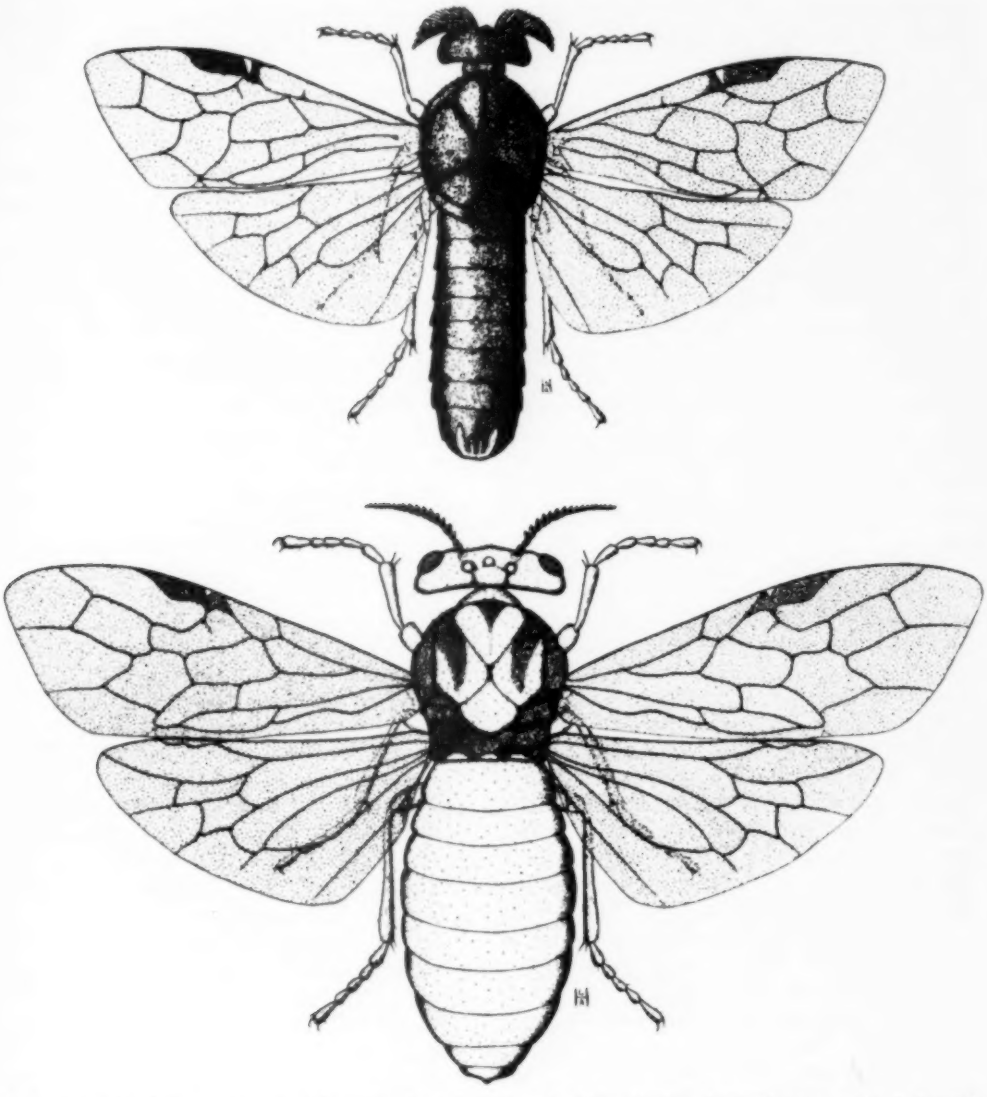


FIG. 4.—*Neodiprion americanum*. Above, male, below, female. (Length, female 8–10 mm., male, 7–8 mm.)

larvae had a peculiar medicinal odor and desiccated specimens could be found under infested trees a month or more after feeding was completed. No fruiting bodies of fungi could be found on the desiccated specimens. The cause of this condition is undetermined, but it is believed that it was the result of bacterial or virus infection. Although this disease was again noted in May 1940, it was not so prevalent as it had been during the 1939 season.

Another disease, apparently caused by a fungus, attacks the prepupae in their cocoons in the soil. Prepupae killed by this disease are firm, and fruiting bodies are sometimes growing from the dead specimens.

Five species of insect parasites have been reared from cocoons of *Neodiprion americanum*. Adults of these parasites have been commonly observed in infested areas. Parasitic Hymenoptera were determined by R. A. Cushman, and the Diptera by C. T. Greene and D. G. Hall, all of the staff of the United States National Museum. The most important parasite is a black and yellow banded ichneumon fly, *Exenterus flavisimus* Cush. The adult

wasps emerge in April and May and are abundant throughout the feeding period of the sawfly larvae. Another less important ichneumon parasite is *Stylocryptus subclaratus* Say. A black bombyliid fly, *Anthrax sinuosa* Weid., was reared from many of the cocoons of *N. americanum* and these flies were very abundant in the infested areas. Two tachinid flies, *Spathimeigentia spinigera* Tns. and *Phorocera claripennis* Macq., have also been reared from the sawfly cocoons but these species have not been very abundant.

Hemipterous predators destroy adult sawflies during the oviposition period. Spiders, web-builders and non-web-builders, are also of some importance in reducing the population of adults of *Neodiprion americanum*. Because of their sluggish habits, the female sawflies are easy victims of these predators.

KNOWN INFESTED AREAS.—During 1939 the only known areas of infestation of pine by *Neodiprion americanum* were an extensive area in King and Queen County, near Walkerton, Virginia, and another isolated area in Mathews County. During 1940 infestation was found in scattered sections of King and Queen, King William, and Caroline counties. From the soil population studies it is evident that the infestation near Walkerton has been active for a number of years, whereas the infestations found in 1940 are all of more recent development.

Although defoliation of closed stands of pine has been observed, infestation is more common in areas which are understocked with pine and where the trees retain their lower branches. Most of the infestations are confined to areas of fine sandy soils.

POSSIBILITIES OF CONTROL.—Pine trees in the infested areas do not seem to be severely injured by defoliation occasioned by the feeding larvae of *Neodiprion americanum*. This may be explained by the fact that larval feeding during May is confined to the old needles. The new growth develops during June and July and seems to take care of the requirements of the trees. No bark beetle outbreaks have followed the sawfly defoliation. It is to be expected that defoliation interferes with the production of wood. Increment cores from defoliated trees show that the "spring" or soft wood production is nearly normal but that the pitch ring is less than normal. This is what might be expected because the pitch is manufactured in the old needles and not transferred to the wood of the trees until late summer prior to the normal shedding of these needles in October. The body content of the sawfly larvae is very resinous as a result of the habitual diet of pine needles.

Several small-scale spray applications were made to test the effectiveness of arsenicals against the larvae of this sawfly. Arsenate of lead 3 pounds to 100 gallons or calcium arsenate 8 pounds to 100 gallons plus calcium caseinate as a sticker provided effective protection for sprayed pine trees. The spray application must be made when the larvae are young in order to obtain control and to protect the trees. Arsenical sprays should be useful and practical for the protection of pine trees that have an ornamental value.

A knowledge of the life history of *Neodiprion americanum* suggests a method of control that is more practical from the standpoint of forest management. During the winter of 1939–40 tests were conducted to determine the effect of winter cutting of pine trees containing eggs of *N. americanum* in their tops. It was found that the drying out of the needle tissues also caused the desiccation of the sawfly eggs. Any cutting operation that would be completed prior to the hatching of the eggs would insure control for that season. The trees could be profitably marketed as pulpwood. Such a procedure would mean that the spring-emerging parasites would have a better chance at any infestation that might have been overlooked. The fact that some of the sawflies carry over one full season in the soil must be taken into consideration. Since the adult female sawflies seem to be poor fliers, it is not likely that they would travel very far from their points of emergence. Some of them would undoubtedly reach the periphery of the cut-over area to deposit their eggs. Adequate scouting and cutting of trees during the second winter would be necessary to insure control. Such a campaign would be justified if the sawfly should threaten the production of pine timber in Tidewater, Virginia; however, the problem of land utilization after the trees had been removed is another consideration.

SUMMARY.—During the past several

years a sawfly, *Neodiprion americanum* (Leach), has caused defoliation of pines in scattered areas in eastern Virginia. Adult sawflies emerge in October and deposit eggs in the needles of the top branches of pine trees 20 to 30 feet tall. The eggs pass the winter in the needles and hatching takes place late in April or early in May. Larval feeding is completed by early June and the prepupae penetrate the soil to a depth of several inches where they spin cocoons. Pupation takes place in September. Adult sawflies remain within their cocoons about one week prior to emergence in mid-October. Some prepupae carry-over in their cocoons in the soil until the autumn of the following year. There is only one generation each year according to observations made up to the present.

Due to the fact that the sawfly larvae eat only the old needles of the pines, the trees are not killed by repeated defoliation; however, wood production of defoliated trees is reduced. No outbreaks of bark beetles have been noted to follow defoliation by *Neodiprion americanum*.—12-28-40.

Longhorned and Flatheaded Borers Attacking Fire-Killed Coniferous Timber in Michigan[1]

FRANK T. PARMELEE, *Department of Entomology Michigan State College, East Lansing*

Wood-boring insects, chiefly beetles, often do a great deal of damage to dead standing or fallen timber, which would be highly merchantable were it not for their depredations. Losses following fires and windstorms in coniferous forests, especially if death of the trees occurs at a time when the adult beetles are flying, have been reported as high as 50 per cent in three years and commonly 100 per cent in three or four years (Hopkins 1912). Wood rotting fungi which reach the heartwood of dead trees through borer tunnels complete such a thorough job of deterioration that infested timber is often worthless even for firewood.

Objectives.—This investigation continued through 1937, 1938 and 1939 and was designed to determine what species of beetles were responsible for damage to fire-killed coniferous timber in Michigan and the effect of heavy concentrations of such secondary forest insects within a burned-over area on the surrounding uninjured trees. Studies of the degree of infestation of storm-felled coniferous trees and slash from cuttings as compared to the degree of infestation of fire scorched timber from the same locality were made in order to determine the attractiveness or repellent effect of scorched bark to ovipositing female beetles.

METHODS, EQUIPMENT, AND PROCEDURE.—The collection of material for this study was begun in the fall of 1937 and continued through 1938 and 1939. During that time several truck loads of infested, fire-killed, storm-felled, and slash, coniferous timber was cut from various Michigan localities and brought to the laboratories at East Lansing for study. Infested material from native Michigan jack pine, *Pinus banksiana* (Lamb); white pine, *Pinus strobus* (L.); Norway or red pine, *Pinus resinosa* (Ait.); balsam fir, *Abies balsamea* (L.) (Mill.); American larch, *Larix laricina* (Du Roi) (Koch); and black or bog spruce, *Picea mariana* (Mill.), was cut into suitable lengths and placed in screen cages of a mesh size adequate to prevent escape of small insects. For each cage of material left out of doors under natural conditions a corresponding cage of material from the same tree was placed indoors. Each was given a number so as to indicate that the wood came from the same tree. Individual records were kept for all trees brought to the laboratory. Insects emerging from the wood in the various cages were given their proper numbers and dates of emergence.

The wood caged indoors was kept in a greenhouse at a temperature of between 60° and 70°F. The moisture content of the material was kept as favorable as possible for the immature insects by weekly applications of water.

The presence of red ants in the greenhouse caused difficulty, especially during the first year; these pests sought out and

[1] Authorized for publication as Journal Article No. 504, Mich. Agr. Expt. Station.

Table 1.—Woodboring beetles reared from fire-treated and check white pine logs and limbs, East Lansing, Michigan 1937–1938.

Species Reared	Number Reared 6½″ Diameter		Number Reared 3½″ Diameter		Average Number Beetles Reared per Square Foot of Bark Surface			
	Logs*		Limbs		Logs		Limbs	
	Scorched	Check	Scorched	Check	Scorched	Check	Scorched	Check
Monochamus scutellatus (Say)	27	19	10	16	1.35	.95	.50	.80
Pogonocherus mixtus (Hald.)	28	34	18	12	1.40	1.70	.90	.60
Astylopsis guttata (Say)	11	17	12	14	.55	.85	.60	.70
Asemum moestum (Hald.)								.40
Chrysobothris dentipes (Germ.)	3	9	10	16	.15	.45	.50	.80
Totals and Averages	69	79	50	58	3.45	3.95	2.50	3.30

* Logs totaled 20 sq. ft. bark surface for each log.

destroyed many wood boring larvae before the infestation could be checked. Further trouble from this source was prevented by a thorough clean-up of hiding places and by placing the cages on long, low, rack-like tables supported by legs immersed in shallow pans of oil. Tanglefoot was smeared on the supporting rack between cages to prevent the migration of the ants from cage to cage.

1937 MATERIAL.—Infested wood was obtained only from East Lansing for study during 1937. A number of recently cut white pine logs and limbs were scorched by burning kerosene smeared over the surface of the bark. These logs and limbs were placed in a sunny spot on May 13, 1937. At the same time an equal number and size of white pine logs and limbs which had not received the superficial burning treatment were placed in the same locality. All wood was collected and caged on September 20, 1937. At the time of caging nearly every piece of wood was invested.

Table 1 shows the number and species of beetles reared from outdoor cages. While several species contributed to the deterioration of the wood, most of the serious heartwood damage was caused by the white-spotted sawyer, *Monochamus scutellatus* (Say). The Cerambycid, *Asemum moestum* (Hald.), reached the heartwood of the white pine limbs but scarcity of this species lessens its importance. The superficial burning treatment seemed to

Table 2.—Woodboring beetles reared from white, jack and red pine fire-killed and slash timber, Roscommon, Michigan, 1938–1939.

Species Reared	White Pine		Jack Pine		Red Pine	
	Slash 30 Sq. Ft.	Scorched 40 Sq. Ft.	Slash 30 Sq. Ft.	Scorched 40 Sq. Ft.	Slash 30 Sq. Ft.	Scorched 40 Sq. Ft.
Monochamus scutellatus (Say)	39	58	27	43	13	28
Monochamus titillator (Fab.)	19	4	15	3	2	3
Monochamus notatus (Drury)		2				
Acanthocinus pusillus (Kby.)	5	11	2	3	3	4
Rhagium lineatum (Oliv.)	2					
Callidium antennatum (Newn.)	1	1				
Anoplodera canadensis (Fab.)		1				
Chrysobothris blanchardii (Hotn.)	6	2				
Chrysobothris scabripennis (C. & G.)	67	5				
Chrysobothris dentipes (Germ.)	5	2	3		3	1
Chalcophora virginiensis (Drury)		7				
Totals	144	93	47	49	21	36
Average Beetles Per Sq. Ft.	4.8	2.3	1.6	1.2	0.7	0.9

Table 3.—Woodboring beetles reared from fire-killed timber of five tree species from Presque Isle fire area, Onaway, Michigan, 1939–1940.

	Pinus banksiana	*P. strobus*	*P. resinosa*	*Abies balsamea*	*Picea mariana*
Approximate Sq. Ft. Bark Surface	100	50	50	25	100
Species Reared					
Monochamus scutellatus (Say)	63	38	11	13	23
Acanthocinus pusillus (Kby.)	5	9	1		14
Astylopsis guttata (Say)		7			
Totals	68	54	12	13	37
Av. No./ Sq. Ft.	68	1.08	.24	.52	.37

have a repellent effect as more adult beetles emerged from the check logs than from the burned ones.

1938 MATERIAL.—Borer-infested white, red and jack pine timber was obtained from near Roscommon, Michigan, on November 7, 1938. A considerable area had been cut over during the previous winter and all slash was left in the clearing. A small fire occurring in May, 1938, had destroyed some of the slash and killed a few of the surrounding red, white and jack pine trees. All fire-killed trees and slash were heavily infested with borers. Table 2 shows the amount of slash and fire-killed borer-infested timber collected from Roscommon, Michigan, and the number and species of wood-boring beetles reared from it.

In addition, infested jack pine and balsam fir timber was collected from the Huron National Forest in Oscoda and Crawford counties and infested larch and balsam fir from near Whittemore, Michigan, in Iosco County. From outdoor and indoor caged material from these localities *Monochamus scutellatus* (Say) was the principal beetle reared. From approximately 70 square feet bark surface of infested fire-killed larch and balsam fir from Whittemore, Michigan, 54 specimens of *M. scutellatus* were reared; from approximately 125 square feet bark surface of infested storm-felled balsam fir and jack pine from the Huron National Forest, 148 specimens of *M. scutellatus* were reared. These counts further indicate that fire-killed timber does not necessarily attract ovipositing beetles because of the effect of the burning.

Uninjured trees surrounding the small burned over area near Roscommon apparently were not affected by the concentration within it, either from secondary wood-destroying insects or bark-beetles.

1939 MATERIALS.—Material for study during the winter of 1939–1940 was obtained from a large burned-over area in northern Montmorency County. This fire, known as the Presque Isle fire, was uncontrolled from May 6 to May 8, 1939, during which time nearly 30,000 acres of coniferous forest land was burned over, killing or critically injuring most of the trees thereon. Jack pine, *Pinus banksiana* (Lamb), was the dominant tree species over the whole area, but other native Michigan conifers were generally distributed throughout.

Samples of borer infested timber were cut at random from this locality on October 4, 1939, and caged indoors on November 11, 1939. Table 3 indicates the number and species of wood-boring beetles reared from the various samples of infested timber. Here, again, *M. scutellatus* caused most of the damage. Fungal infection in the heartwood of logs was observed only where such regions were penetrated by the tunnels of this sawyer. The large Buprestid, *Chalcophora virginiensis*, reported by Buttrick (1912) as chiefly responsible for injury to fire-killed timber in the Black Hills of South Dakota, was apparently absent in the Presque Isle fire area. Dunn (1931) and Swaine (1916) consider the grey sawyer, *Monochamus notatus*, as a most important secondary borer attacking fire-killed or storm-felled timber in northeastern Canada. Such does not seem to be true in Michigan, as very few individuals of this species were reared over a period of three years from any locality.

Observations made during the summer of 1939 did not indicate the heavy concentration of secondary borers within the fire area as a menace to neighboring healthy trees. Some fire injured trees which otherwise might have recovered

were attacked and their death hastened by bark-beetles but no successful attacks on vigorous trees were noted.

Parasites and predators did not appear to be of much importance in destroying wood boring larvae in the Presque Isle Fire Area. Woodpeckers were fairly numerous but their prevention of much damage is questionable. The Hymenopterous parasite, *Ichneumon mesocentrus* (Gravenhorst) was the most numerous of the sawyer parasites reared.

CONCLUSIONS AND SUMMARY.—Fire-killed coniferous timber in Michigan does not appear to have any more attraction to wood-boring Coleoptera than timber killed by other agencies. Scorched trees are readily attacked and damaged but emergence records indicate that slash and storm-felled trees are even more heavily infested. Timber killed by any agency is more attractive to wood-boring Coleoptera during the first year after death of the trees. While certain species prefer wood in a more advanced stage of decay, these are of little importance as far as injury to timber is concerned. Borers such as the sawyers require freshly killed trees and will not as a rule re-infest trees from which they emerge as adults. Examinations of dead timber caused by spring fires revealed heavy damage to merchantable timber by secondary wood borers. The bulk of this injury was confined to the trunks and larger branches; damage to small trees (3-inch diameter and less) as well as the smaller branches of larger trees was negligible.

Rather limited examinations of forest trees surrounding Michigan slashings and burned-over areas indicated that such areas are not a menace to adjacent healthy timber. The concentration of secondary wood borers in burned-over areas is often very high, resulting in the death of some fire injured trees which, without further attack by these borers, might have recovered, but it does not appear that borers attacking dead timber can successfully adapt themselves to breeding in healthy trees to any great extent.

The white-spotted sawyer, *Monochamus scutellatus* (Say), was responsible for nearly all damage to dead coniferous timber observed in Michigan. While other species of wood-boring beetles contribute to the ultimate destruction of the wood, they are not present in large enough numbers to be considered of much importance. A study of the biology of the white spotted sawyer indicated that under normal conditions in Michigan the developmental period is one year. Individuals developing under adverse moisture or light conditions may require a much longer time. Natural control of wood-boring beetles by parasites and predators did not seem to be of much significance in the areas investigated. Woodpeckers and hymenopterous parasites of the family Ichneumonidae appeared to be of the most importance.

Larval counts and adult emergence records of Michigan fire-killed timber indicate white pine, *Pinus strobus*, as the favorite host for sawyers as well as other wood-boring Cerambycidae and Buprestidae. These records show Norway pine, *Pinus resinosa*, to be much less heavily infested than other coniferous tree species. —1-14-41.

LITERATURE CITED

Buttrick, P. L. 1912. Notes on insect destruction of fire-killed timber in the Black Hills of South Dakota. JOUR. ECON. ENT. **5**: 446–64.

Dunn, M. B. 1931. An investigation of *Monochamus* beetles and their control. 22nd Ann. Rep. Quebec Soc. Prot. Plants, 86–8.

Hopkins, A. D. 1912. Damage to the wood of fire-killed Douglas fir and methods of preventing losses in Western Washington and Oregon. U. S. Dept. Agr. Bur. of Ent. Circ. **159**.

Swaine, J. M. 1916. Some features of interest in connection with our studies of forest and shade tree insects. Ont. Ent. Soc. Report, **47**: 96–7.

The Governor of Illinois on the recommendation of the State Department of Agriculture revoked the quarantine and regulations of that State, relating to the European corn borer, which placed restrictions on the entry of corn and other host plants from the designated infested States. The proclamation became effective April 1, 1941.

California's Proclamation No. 3 pertaining to the oriental fruit moth as revised effective April 9, 1941, provides for the entry of bare-rooted host trees beyond the dormant period, November 1 to April 1, provided such trees are shipped from an approved storage place and have received the required treatment before being placed in storage.

A Beetle Control Problem in Timbers of the Old South Meeting House

DONALD M. MUIRHEAD, *Muirhead & Holway, Inc., Duxbury, Mass.*

The hand hewn oak timbers in the steeple of this historic building in Boston, Massachusetts, were attacked and structurally weakened by the activity of *Xestobium rufovillosum* DeG., the death watch beetle.

The extent of the infestation was first discovered in 1937, although several years previous to this the roof and roof timbers of the building proper had been completely renewed. No written evidence has been found which would indicate that any attempt had been made to determine the nature of the destructive organisms which necessitated these renewals.

An inspection of these old timbers revealed severe *Xestobium* infestation and many were useless. It is quite probable that these were infested while in the old roof and that *Xestobium* damage was the real cause of structural damage in the old roof.

It is interesting to note that engineers who saw the damage to the tower timbers say that if repairs had not been made, the tower would certainly have been carried away by the hurricane of 1938.

CONDITIONS.—The framing of the tower is a series of tapered octagon sections formed with hand hewn oak timbers. "Spider web" platform framing between sections provides a cantilevered support for the higher sections as well as horizontal bracing. The large upright timbers at the points of the octagon are approximately 12″×12″ and the platform main timbers are approximately 8″×8″. All connections were made with mortise and tenon, and pinned with oak pegs (Fig. 1).

Damage had been caused in the centers of these large timbers, although the exterior appeared sound except for exit holes and dropping frass. This dropping frass which accumulated in small piles on the platform floors first called attention to the infestation. Most of the exit holes occurred in checks or on the inner surface of the mortises and were hidden from view.

It should be noted that approximately 10 years previous to this examination, a brush coat of a proprietary creosote compound had been applied to the surface of all timbers in the tower. No attempt had been made to prepare or clean the timbers for this treatment and in many cases the material had been applied directly over bark or whitewash.

This treatment had not affected the larvae working within the timbers, but may have been a factor in the concentration of activity toward the center of the timbers (Fig. 2).

FIG. 1.—Exit holes at mortise joint.

Although many timbers were so badly damaged that replacement or reinforcing was necessary, many were still structurally sound and less heavily infested.

The Committee desired to save as many of the original timbers as possible and having stored some of the sound original roof timbers, they also wished to make renewals or repairs with these.

TREATMENT.—The best of the old roof timbers were selected and, after cleaning, were submerged in orthodichlorobenzene for a two week period, after which they were used for necessary replacements.

Core sections were taken from the infested tower timbers and their relative structural strength determined from the percentage of sound wood appearing in these core sections. All timbers were then cleaned down with electrically driven wire

brushes, all bark, paint and whitewash being removed during this operation. Where beetle galleries were near the surface, the damaged wood was cut away and where the galleries were near the center of compression timbers, small holes were bored extending from the surface to the galleries. A rubber cup attached to a strong vacuum machine was then used over all exit holes and borings and by rapping the timbers sharply with a wooden mallet, much of the frass was loosened and then removed by suction.

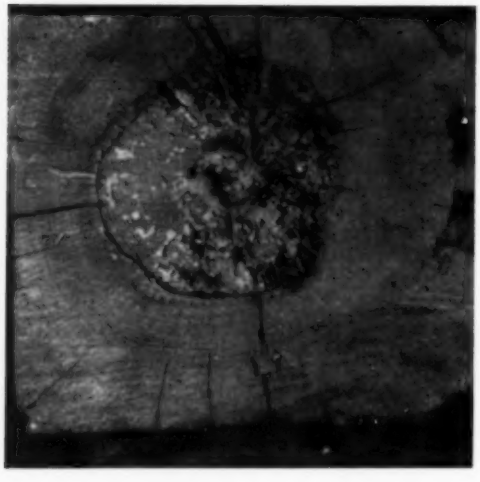


FIG. 2.—Concentration of work toward the center of the timbers.

In certain places where leaks occurred in this closed tower, the wood was damp and it was in these areas that beetle damage was most severe. English workers (Fisher 1935) on similar problems had found a very definite acceleration in the life cycle of *Xestobium* in wood having a high moisture content and advanced fungus infection. The complete cycle varied from 11 months to 30 months during experiments conducted with *Xestobium* in wood with varying moisture content and fungal infection. These workers concluded that "development of *Xestobium* in buildings is extremely slow unless conditions are favorable to rapid decay."

The previous sealing of all openings in the tower to exclude birds and the numerous small leaks combined to maintain a high moisture content in the tower timbers and thus created conditions favorable for rapid decay. It was therefore evident that ventilation should be introduced within the tower and that all leaks should be stopped.

Continuous temperature records were taken over a two week period, and periodic air moisture contents were determined, as well as rate of evaporation. This latter determination was made with standardized "Livingstone spheres."

From this data, an attempt was made to predetermine the amount and spacing of vents and periodic air velocity readings were taken at each opening as a check. Having had no accurate formulae to follow in establishing this ventilating system we believe it a matter of good fortune rather than of design that it functioned well and lowered the moisture content to the point where fungus growth was inhibited without additional vents.

After a drying-out period the timbers were considered ready for treatment. Orthodichlorobenzene was selected for the first treatment because of its toxicity and its penetrative power as a vapor as well as a liquid. A hollow "needle" point was mounted on a standard air gun and the liquid was placed under high pressure in the tank container. By inserting the needle in exit holes, borings, checks, mortises and peg holes, the operators were able to force the orthodichlorobenzene into all remaining beetle galleries and to reach all hidden surfaces (Fig. 3). This operation was repeated and the surfaces of all timbers were then treated with the liquid by using the regular spray gun attachments.

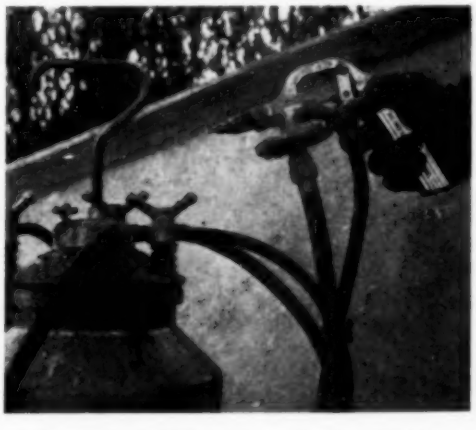


FIG. 3.—Apparatus used to inject liquid into timbers.

Operators and inspectors were equipped with tight rubber masks fitted with long air hoses. These hoses extended from the mask to outside air. Operators, with their attendants, worked for 30 minutes and rested in the open air for 30 minutes. One operator suffered some nausea on his first try, probably because of an improperly adjusted mask, but he later reported with the others that the only discomfort was caused by perspiring within the rubber mask.

When the treatment had dried all timbers were treated in an identical manner with a light creosote. Creosote was selected for the final treatment because of its lasting toxicity. Reinfestation might occur as the orthodichlorobenzene treatment evaporated and it was believed that creosote, protected from the weather, would furnish protection over a much longer period of time.

The work was completed in the spring of 1938, and careful examination has revealed no evidence to date of further beetle activity.—12-28-40.

LITERATURE CITED

Fisher, R. C. 1935. Duration of life cycle of the death watch beetle. Nature 135 (3403) 102–3.
Fisher, R. C. 1937. Biology of *Xestobium*. Ann. of Appl. Biol. **24**: 600–13. Cambridge.
Fisher, R. C. 1937. Recent research on wood-destroying insects. Jour. Royal Soc. Arts. 85 (4400): 407–25. London.

New and Unusual Shade Tree Pests

E. P. FELT and S. W. BROMLEY, *Bartlett Tree Research Laboratories, Stamford, Conn.*

DARK TUSSOCK MOTH, *Olene basiflava* PACK.—Young caterpillars of this species were observed at Stamford, Conn., on slippery elm and white oak in August and again in October 1938. It also feeds on other oaks, as well as beech, flowering dogwood, pecan and hickory. The species was evidently somewhat abundant since it was reported from various localities in this general area. The small larvae only about a quarter of an inch long left the foliage in early September and assembled on the rough bark of larger branches and the trunk in unprotected clusters 6 to 8 inches long and bordered with scattered strands of silk. They wintered in these unprotected masses and in the spring commenced feeding on the young leaves as they pushed out of the bud, their operations being confined mostly to the lower branches. This latter is important since it may explain the weakness and dying of lower branches of oak and other food plants due to the practically complete destruction of the developing leaves in the early spring. It means a maximum amount of injury with a minimum feeding and a type of damage which presumably has been overlooked in years past. This is not serious on forest trees but is of considerable importance on roadside and ornamental trees.

The early spring feeding on the young leaves soon denudes the branches and the caterpillars scatter in May, probably about the middle of the month, to higher branches and there follows a period of more scattered feeding which results in ragged leaves but much less damage to the foliage of the affected branches than is the case with the earlier work. Late in July many oaks along roadways and at the edges of woods showed marked skeletonizing of the foliage on the outer and lower branches, this condition becoming more apparent during the latter part of August. It was at first thought this might be the work of a sawfly skeletonizer but on closer examination the rows of small yellowish tussock caterpillars were observed feeding.

This tussock caterpillar, although presenting a general resemblance to the white-marked tussock moth, can be easily recognized by the dark brown head concealed with yellowish clusters of barbed spines, the thick median brushes of dark brown hairs on the first to fourth abdominal segments and the short median radiating groups of mostly whitish club-shaped hairs. The larvae become full grown about the middle of June and spin a loose open cocoon with entangled hairs on the rough bark of the host tree, the adults emerging from July 10 to August 9. Twenty-four moths were reared and sent to the Bureau of Entomology and Plant

Quarantine for identification. They were provisionally identified by Dr. J. F. G. Clarke as the above named species though he stated that the complex is an exceedingly difficult one to identify and added that later critical study may alter our present concepts of the specific limits. It appears possible that *Olene atomaria* Walker, *O. parallela* Gr. & Rob., *O. cinnamomea* Gr., *O. clintonii* Gr. & Rob., and *O. vagans* B. & McD., may prove to be synonyms. The pale green eggs, each flattened on the top and with a diameter of about one-fiftieth of an inch, were deposited from July 14 to 18 in oval clusters of some 250 eggs or more lightly glazed with an iridescent substance. Hatching occurred July 27. Several parasites were reared, one *Exorista larvarum* L., being identified at the National Museum.

THE RED-HUMPED OAK CATERPILLAR, *Symmerista albifrons* ABB. & SM.—This native, usually inconspicuous species, was exceptionally abundant in September 1940 on several species of oak, beech, chestnut and birch and was reported from a number of localities in southern New England.

THE SNOW-WHITE LINDEN MOTH, *Ennomos subsignarius* HUBN.—This moth was extremely abundant in midsummer on maple in a twelve hundred acre swamp at Wenham, Mass., several hundred acres being defoliated. Red maple suffered most, though there was some feeding on white oak, viburnum, beech, elm and even on goldenrod. A noteworthy feature of the outbreak was the lightly-webbed strings of partly eaten leaves an inch to an inch and a half wide and several feet long. These webbed masses also contained cast skins or the dead remains of partly grown larvae. This is the species occasionally extremely abundant on beech in the Catskill Mountains of New York state, hosts of the snow-white moths appearing at lights in midsummer.

BLACK WILLOW GALL (POSSIBLY *Rhabdophaga cornuta* WALSH).—Work of this gall-maker was abundant and seriously injurious to black willow both at Greenwich, Conn., and at Princeton, N. J. Trees 15 to 25 feet in height and 5 to 9 inches in diameter were so seriously affected through a series of years that some 50 per cent of them were in a dying or dead condition. The infestation was somewhat definitely limited to twigs a quarter of an inch in diameter, the wood being approximately four years old. The sapwood was thickly pitted with larval cells which were so close together that woodpeckers tore off bark over areas 6 to 12 inches long leaving coarse hanging shreds. There was no evidence of attack on the younger wood although that beyond the injured areas was killed. Adults, as well as a number of parasites, were reared the latter part of May. Spraying with a nicotine, soap and molasses combination early in May is a promising control measure.

PINE ROOT WEEVIL, *Hylobius radicis* BUCHANAN.—This relatively new insect, it was not described until 1934, is developing into something of a pest in southwestern New England and southeastern New York. Moderately serious infestations were located the past season in both Greenwich and Stamford, Conn., and more serious damage was brought to notice the preceding year in New Canaan, Conn., a number of Austrian pines with trunk diameters of 6 to 8 inches in the last named locality having been killed and from the stumps 10 specimens of this weevil were reared. Full grown larvae from this lot were observed June 29, 1939, three adults being found alive in the cages December 24, indicating that they would hibernate as adults.

An unusual feature was the rearing of only four *Hylobius radicis* from five pine stumps collected at Greenwich, Conn., and 36 specimens of *Pissodes approximatus* Hopk. This latter insect is closely related to the much better known *P. strobi* (Peck) and occurs somewhat commonly in the thicker bark of sickly pines. It is not a tip-infesting insect. *P. approximatus* Hopk. has been reared from the lower part of pine stems earlier but in no case has there been such a number as recorded above. It is probable that the *Hylobius* work noticed above produced conditions attractive to the Pissodes.

No satisfactory control measure for *Hylobius* has been developed as yet.

SMALLER EUROPEAN ELM BARK BEETLE, *Scolytus multistriatus* MARSHM.—Experiments in 1937 showed a striking difference between the feeding of this insect on potted sprayed and unsprayed elms. The data were published by the authors (Felt & Bromley 1938). Owing to the scarcity of material, further tests were not possible until 1940. Then small potted

elms in cages were stocked, both the sprayed and the unsprayed tree with 44 beetles each, the adults being added as they issued from June 6 to 20. The spray was arsenate of lead 6 pounds and a spreader 8 ounces to 100 gallons of water. The spray was allowed to dry before any beetles were put in the cage. Observations made July 1 showed 4 crotch feeding punctures on the sprayed tree and 44 on the unsprayed tree. There were no dead or hanging twigs or living beetles in the cage with the sprayed tree, while in the other there were 6 dead and hanging twigs and 6 living beetles, 5 of these feeding in the crotches. These data confirm most satisfactorily the results obtained in 1937.

A JAPANESE LEAF HOPPER, *Phlepsius ishidae* MATS.—Dr. B. O. Dodge of the New York Botanical Garden sent in specimens of both apple and hazel foliage showing somewhat large, uniformly browned areas on the leaves and an evident infestation by young and adult of this leaf hopper, which latter was identified through the courtesy of Dr. C. F. W. Muesebeck of the U. S. Bureau of Entomology and Plant Quarantine. The injured leaves showed no indication of stippling or mottling so frequently associated with leaf hopper attack. This species was discovered by Matsimura in 1902 and was first recorded in North America in 1919 by Sanders and De Long under the name of *Phlepsius tinctorius*. It has been recorded, in addition, from Irvington and South Orange, N. J., Bristol, Pa., and Annapolis and Crisfield, Md. It has also been reported from Babylon, Long Island, Pierce Bridge, N. H., and Washington, D. C. It was quite possibly introduced in the egg stage on shrubs of *Aralia*.

ELM WEBWORM, *Tetralopha asperatella* CLEM.—An unusual condition on slippery elm leaves at Stamford, Conn., was brought to notice September 19, 1940. A dark brown, dull yellowish-striped caterpillar about an inch long was feeding on the intervenal areas on the underside of the leaves and webbing the foliage together in a firmer though somewhat smaller mass than that produced by the fall webworm. The large amount of dead foliage, much comparatively unharmed, suggests that the leaves were largely pulled off by the webbing and this was confirmed by the fact that many of the petioles of these uninjured leaves were free from the branch though held approximately in place by the webbing. The tentative identification was obtained through the U. S. Bureau of Entomology and Plant Quarantine. Presumably the same species was somewhat abundant on pin oak, and has also been noted rather commonly on sugar maple.

TULIP TREE SCALE, *Toumeyella liriodendri* GMEL.—This scale has been extremely abundant on a small tree at the Bartlett Tree Research Laboratories for several years and in 1939 there developed an infection with a fungus so general, probably due to the prevalence of cold, rainy weather, that a considerable proportion of the scale insects were whitened. This material was sent to the Bureau of Plant Industry and up to the present no identification has been obtained. The larvae of the two-spotted lady beetle, *Chilocorus bivulnerus* Muls., were so numerous as practically to eliminate the infestation by this scale insect.

OAK ROSETTE GALL, *Andricus flavohirtus* BEUTM.—A most unusual condition came to light through the receipt from Easton, Mass., of swamp white oak twigs galled by this species accompanied by the statement that 90 per cent of a large tree was literally in this condition. The galls themselves contained a central oval cell about three-sixteenths of an inch in diameter and in the judgment of Mr. L. H. Weld the cells now in the galls in late fall were those of a guest fly, *Ceroptres frondosae* Ashm., while the galls of the true producer, the insect named above, had dropped to the ground and would produce adults the following season.

An additional complication was seen in the crowded rudimentary leaves around the cells of the gall makers. They were generally infested with six to eight small maggots of a gall midge. The species has yet to be determined by rearing. The infestation throughout the tree was so abundant that a large proportion, approximately 90 per cent, of the twigs were tipped with galls, really distorted masses of rudimentary leaves.

ELM LEAF SPOT GALL MIDGE, *Cecidomyia* SP.—Leaves with rounded elevations on the upper side and in the depression on the undersurface white maggots one-fortieth of an inch long were found, some ovate in form, a few larger, elongate, one-twenty-fifth of an inch long and moder-

ately active. These elevations were mostly beside the veins. This condition was found in earlier years near Philadelphia, Pa., in several Connecticut localities near Danbury, and the past season at Stamford.

The affected areas, as they age, turn a brownish-purple around the edge and then assume a uniform brown with an extremely small white pellicle on the under surface. The general appearance is then similar to that of the frog-eye leaf spot on apple and for a time it was thought it might be a fungous infection. June 3 the maggots had all dropped from the elm leaves at the Laboratories although they were somewhat common May 29.

Two leaf galls, namely the maple leaf spot, *Cecidomyia ocellaris* O. S., and the dogwood spot gall, *Lasioptera corni* Felt, were unusually abundant the past season. Considerable material has been collected and it is hoped to rear the insects another spring and establish the identity of the maker of the first-named and confirm, if possible, our determination of the producer of the second.—12-28-40.

LITERATURE CITED

Felt, E. P., and S. W. Bromley. 1938. Shade tree insects and sprays. 1937. JOUR. ECON. ENT. **31**(2): 173–6.

Coryphista meadii (Packard), a New Pest of Japanese Barberry

C. R. NEISWANDER, *Ohio Agricultural Experiment Station, Wooster*

Early in July 1940, a number of hedges of Japanese barberry were almost completely defoliated at Wooster, Ohio (Fig. 1), by a geometrid caterpillar. During the day, the caterpillars remained concealed in the litter under the hedge or among dead leaves lodged in the axils of branches. Early in the evening, and sometimes also on dark, cool days, the caterpillars left their sheltered positions and crawled to the top of the plants, where they fed first on the newest growth.

FIG. 1.—Section of barberry hedge showing defoliation caused by *C. meadii*. Photograph taken July 17, 1940.

When the adults were reared it was found that they were of two color forms. The dark form (Fig. 2) exceeded the light form in the ratio of approximately 10 to 1. H. W. Capps of the United States National Museum identified the dark form as *Coryphista meadii* (Pack.) and the light form as *C. meadii* f. *badiaria* (Hy. Edw.).

The two forms were originally described as distinct species from the Rocky Mountain area. In 1874 the dark form was described by Packard (1874) from Colorado under the name *Scotiosa meadii*. Henry Edwards (1885) described the light form in 1885 under the name *Triphosa badiaria* from a single female taken in Shasta Co., California. Neither author recorded a food plant. Hulst (1896) described the genus *Coryphista* in 1896 and placed in it the two species *meadii* (Pack.) and *badi-*

FIG. 2.—Adult female, dark form, *C. meadii*.

aria (Hy. Edw.). In 1902, Dyar (1902) gave a description of the egg and four larval stages of the species *C. badiaria* (Hy. Edw.). He reported that larvae were taken on *Berberis repens* from various places in the foothills of the Rocky Mountains, back of Boulder, Colorado, and in Platte Canyon. Twenty-five years later, McDunnough (1927) stated that he believed the distinction between the two forms was variational only and not specific. In his check list McDunnough (1938) lists *badiaria* as a form of *meadii*. To the writer's knowledge the species has never been reported east of the Rocky Mountains.

The known area of infestation in Ohio in 1940 covered more than half the state. It extended from Kent in northeastern Ohio to Marietta along the Ohio River and to Tiffin and Galion in the northwest central area. In the city of Wooster, 10 different plantings were observed to have suffered varying degrees of injury. In Kent, several plantings were completely defoliated. At Marietta, defoliation occurred in the State Forest Nursery, and caterpillars were collected from two other plantings in that general area.

The insect was taken on four varieties of barberry, determined by L. C. Chadwick of Ohio State University to be *Berberis thunbergii* (D. C.), *B. thunbergii minor* (Rehd.), *B. thunbergii atropurpurea* (Chenault), and *B. thunbergii erecta* Rehd. It was taken also on *Mahonia* sp. at Cincinnati in 1938 and at Norwalk in 1940.

LIFE HISTORY.—From July 8, when the infestation was first observed, all stages of the insect could be found until mid-October. From that date on, neither adults nor eggs were seen, but larvae in considerable numbers continued to feed up to November 5. After that date, pupae only were found.

During midsummer, the life cycle was completed in approximately 4 weeks apportioned as follows: egg stage 3 to 4 days, larval stage 14 days, and pupal stage 11 days. Rearing records indicate that there were four or five generations during the year with no demarcation between them.

The eggs were deposited in various positions on the barberry plant. In most instances they occurred singly on the undersurface of leaves. Occasionally, they were found on the upper surface of the leaves and sometimes on leaf petioles, twigs, and spines. On warm evenings, by means of a flashlight, moths could readily be observed depositing eggs on the plants.

The shape of the egg, as given by Dyar (1902), is "elliptical rounded, two sides flattened, wedge shaped, the large end truncate for a small space, all without sharp angles: size .9×.6×.5 mm." During the summer the duration of the egg stage was 3 to 4 days. In the fall when the temperature became lower, the length of the period was somewhat increased.

The larvae are easily reared in the laboratory and grow rapidly if fresh, succulent food is available. During midsummer, 12 to 16 days were required to attain complete growth. In the fall when the foliage became less succulent, larval growth was slow and the mortality high even in the laboratory where a high temperature was maintained.

The full-grown caterpillar is nearly an inch long. The basal body color is dark brown, and the head is orange. On each side of the body a broad, light-colored stripe extends the full length. Located within this stripe are numerous brown areas, also the black spiracles, each of which is surrounded by a blotch of orange. On the dorsum, four narrow white lines extend the full length of the body. The ventral surface is dark but becomes light colored at the posterior end between the two posterior pairs of legs.

The caterpillars feed on the edges rather than on the surface of the leaves; thus the uncomsumed portions present a ragged appearance (Fig. 3). When they become full grown, the caterpillars abandon the foliage and go into the litter or soil at the base of the plant, where they construct a cocoon from any available bits of plant debris or soil particles. They remain within the case as larvae for a day or two before changing to the pupal stage.

In the insectary, pupation has always occurred at the soil surface. In the garden, it usually occurs at the soil surface, but occasionally pupae have been taken in shallow soil crevices and sometimes among dead leaves lodged in the axils of branches. A photograph of a characteristic cocoon and one that has been opened and had the pupa removed is shown in Fig. 4. During midsummer, the length of the pupal period varied from 7 to 13 days with an average of 11 days.

A satisfactory egg record was not ob-

FIG. 3.—Section of barberry twig showing foliage injury and larvae in various positions.

tained from reared individuals although moths captured out of doors oviposited readily in confinement. Apparently the moths are not strongly attracted to lights, as not any were captured in a light trap operated in the immediate vicinity of a moderately infested hedge.

BIOLOGICAL CONTROL.—During the year, five species of parasites from *coryphista meadii* were reared. Two were dipterons, three hymenopterons. All these emerged from host pupae. Of the dipterons, one specimen was determined tentatively by D. G. Hall of the United States National Museum as *Madremyia saundersi* (Will.). Two other dipterous specimens were determined by Mr. Hall as a species of *Phrynolydella* that is apparently undescribed.

The hymenopterons were determined by R. A. Cushman of the United States National Museum. One specimen was identified as *Amblyteles duplicatus* Say; five specimens represented an apparently undescribed species of *Amblyteles;* and five specimens were *Ephialtes aequalis* (Prov.).

One pentatomid predator was observed feeding on a larva. It was determined by H. S. Barber as *Podisus maculiventris* (Say).

INSECTICIDE CONTROL.—On August 3, 1940, experimental control work was started. A barberry hedge in the Experiment Station gardens was divided into twelve 10-foot areas which were designated as experimental units. The experiment consisted of four treatments, each replicated three times. Three days after the insecticide applications had been made, larval population records were taken on all plots by counting the number of living larvae observed on each plot during a 3-minute period. The treatments used and the number of larvae recorded for each plot are shown in table 1.

Table 1.—Results of experimental applications for the control of *C. meadii*.

TREATMENT	NUMBER OF LARVAE OBSERVED			
	Rep. 1	Rep. 2	Rep. 3	Mean
Lead arsenate 1½ lb., water 50 gal.	0	0	0	0
Lead arsenate 1½ lb., *Grasselli Spreader-Sticker* 95 cc., water 50 gal.	1	0	0	.3
Lead arsenate 1 part, talc 4 parts, applied as dust	0	0	0	0
Check, not treated	24	22	15	20.3

The results of the experiment indicate that lead arsenate in any of the formulas used was effective in controlling the insect. Although caterpillars were actively feeding on many plantings up to the middle of October, the areas treated with lead arsenate remained practically free of the insects for the remainder of the season.—12-28-40.

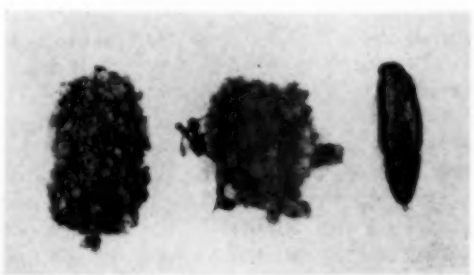


FIG. 4.—Left to right—cocoon, opened cocoon, pupa.

LITERATURE CITED

Dyar, H. G. 1902. Life histories of North American Lepidoptera. Psyche 9(317): 396.
Edwards, Henry. 1885. New species of California moths. Entomologica Americana 1(3): 50.
Hulst, Geo. D. 1896. A classification of the Geometrina of North America with description of new genera and species. Trans. Amer. Ent. Soc. **23**: 275.
McDunnough, J. 1927. The Lepidoptera of the Seton Lake Region, British Columbia. Can. Ent. 59(10): 240.
McDunnough, J. 1938. Check List of the Lepidoptera of Canada and the United States of America (Part I, Macrolepidoptera).
Packard, A. S. 1874. Sixth Report Peabody Acad. Sci., p. 41.

Tube-Building Habits of the Eastern Subterranean Termite

RICHARD T. HOLWAY, *Muirhead & Holway, Inc., Duxbury, Mass.*

An understanding of the tube-building capabilities of the subterranean termite is of fundamental importance in the application of control methods. This subject has not been thoroughly investigated and the many claims as to what termites will or will not do have caused much confusion in the mind of the general public.

This situation seems largely due to the failure of many control operators to recognize the factor of frequency or probability in any particular termite activity. Another source of misunderstanding for the layman is the tendency to attribute the capabilities of a particular genus to termites in general. For example, there are one or two authentic cases in which winged reproductives of the subterranean termites have succeeded in establishing a small colony in a church steeple. Small accumulations of leaves and soil retained enough moisture to make colonization by the royal pair a possibility. There are records of other cases of unusual activity such as the construction of tubes to a height of several feet and of buttressed free standing tubes.

These things are interesting and have considerable popular appeal but their importance from a control standpoint is often exaggerated. Economical control should be designed to deal with the habitual and occasional types of attack, while added expense to protect against rare and isolated forms of termite activity is seldom justified. Very few figures on the frequency of the various types of attack are available and the control designer must depend on his own experience and judgment.

It is obvious that wood in direct ground contact is most subject to termite attack. Of next importance is the common conditions in which wood is open to concealed attack from the ground through masonry joints and cracks or other inadequate barriers.

A third source of trouble may be the use of shelter tubes or runways to travel from soil to wood. It is with this subject that the following observations deal.

The most important factor in the study of tube-building is the direction in which the tube is constructed. It is generally assumed that runways found on foundation walls have been built upward by termites on their way to the wood above. Actually these tubes, in the great majority of cases in the North, are dropped down after the termites have become established in the wood which they have attacked from some easy point of access.

FIELD EXPERIENCE.—Analysis of the history of attack in many termite infested buildings leads to this conclusion. Figure 1 is an illustration of a typical situation found in a partial excavation or basementless area. On the outside, several feet to the left of the tubes, is an entrnace step behind which termites found direct access to the sill. After working along the sill the colony dropped these tubes down to provide a new and more direct soil contact.

Out of several hundred building inspections we have found one doubtful case in which it is possible that original entrance to the building was gained by constructing a runway up over the foundation in a basementless area. Turner (1939) has observed only two cases, in about a thousand, in which the original entry was so made. With few exceptions tubes found on foundation walls have been traced to colonies which had become established in the building at some point, usually hidden, where wood was in ground contact or

where wood could be reached through hollows, voids or mortar joints.

LABORATORY COLONIES.—In order to study more effectively the tube-building habits of these subterranean termites large colonies of *Reticulitermes flavipes* are kept in concrete pits where favorable conditions may be maintained throughout the year. These indoor pits are $4\frac{1}{2}' \times 6\frac{1}{2}'$ and are constructed with reinforced concrete walls and floors. The surface of the three feet of soil placed in the pits is 24″ below the top of the walls.

Observations of termite activity in these pits over a $2\frac{1}{2}$ year period are in accord with field experience gained from inspections of infested buildings. During this time no tubes have been constructed upward to a height of more than 12″ even when the wood supply was completely removed. Only four tubes were attempted and of these one attained a height of 12″, one of 10″, and two of 6″. All of these were constructed in corners. As a matter of fact, whether building up or down, termites seem to go out of their way to find a right angle in which to build. This is probably due to the fact that two sides are ready made and they have only the roof to construct.

It should not be assumed from these observations that Reticulitermes cannot and does not, under certain conditions, construct tubes upward. Anyone who has kept large numbers of termites in small containers without food knows that such activitity usually occurs. It is not uncommon for tubes to be carried to a height of 24″ or more under such conditions. Also, where wood in ground contact stops off against a foundation and a colony has become established in this wood tubes are often constructed upward in search of another food supply.

This would indicate that concentration of population may be an important factor in judging what conditions favor upward tube-building by Reticulitermes. Colonies confined in $\frac{1}{2}$ a cubic foot of soil quickly produce high tubes, whereas many times more termites in the 60 cubic feet of the pits built only 4 short tubes. Possibly in the pits dispersal through the soil in search of food reduced the concentration of termites necessary for extensive tube-building. In small containers the confining walls and bottom would tend to force an upward migration.

This investigation was concerned with general reactions only and controlled experiments have not been attempted. It is hoped that future quantitative tests with measured numbers of termites, volume of soil, and amount of available food and moisture, will produce some correlation between pressure of population and occurrence of upward tube-building.

A factor of considerable importance in the frequency of tube-building is exposure to drying effect of the air or mechanical weathering of storms. For this reason, with few exceptions, tubes are found in dark, poorly ventilated areas. Light (1934) states that Reticulitermes rarely, if ever, builds covered ways over a foundation in the open. This would indicate that the habits of western species of Reticulitermes, in this respect, are similar to those of flavipes. It should be remembered that other genera such as Heterotermes, Nasutitermes and Coptotermes are supposed to exhibit a much greater tendency for upward tube-building than does Reticulitermes.

UNUSUAL TYPES OF TUBE-BUILDING.—The following cases of unusual tube building by Reticulitermes flavipes in the field and laboratory are cited to emphasize the difference between normal and unusual types of activity. This distinction is, of course, artificial and varies with conditions but is significant where these conditions can be economically controlled at any given building.

An unusual occurrence of natural tube-building has been observed at Concord, N. H. Figure 1–(2), shows a creosoted post upon which tubes were built upward to a height of 7 feet. In this instance the new wood was placed in the center of a large colony which had destroyed an existing post. At checks and knots the termites entered to attack wood beneath the limit of penetration of the preservative. Eventually the tube reached the untreated cross timber above, which was attacked. Soon after this picture was taken a severe storm washed away the tube and it was not rebuilt.

The causes of such unusual activity are difficult to determine with any certainty, but it would seem that the size of the colony and the exploration of the treated wood surface for points of access may have led to the extended tube-building.

Construction of tubes downward from

FIG. 1.—1. Tubes built down over foundation wall in partial excavation. Sills were originally attacked at a filled porch. 2. Tube built up 7′ over creosoted post set in center of active colony. 3. Start of tube-building activity after infested log is placed on pit wall. 4. Termites leaving tunnel entrance to travel to soil.

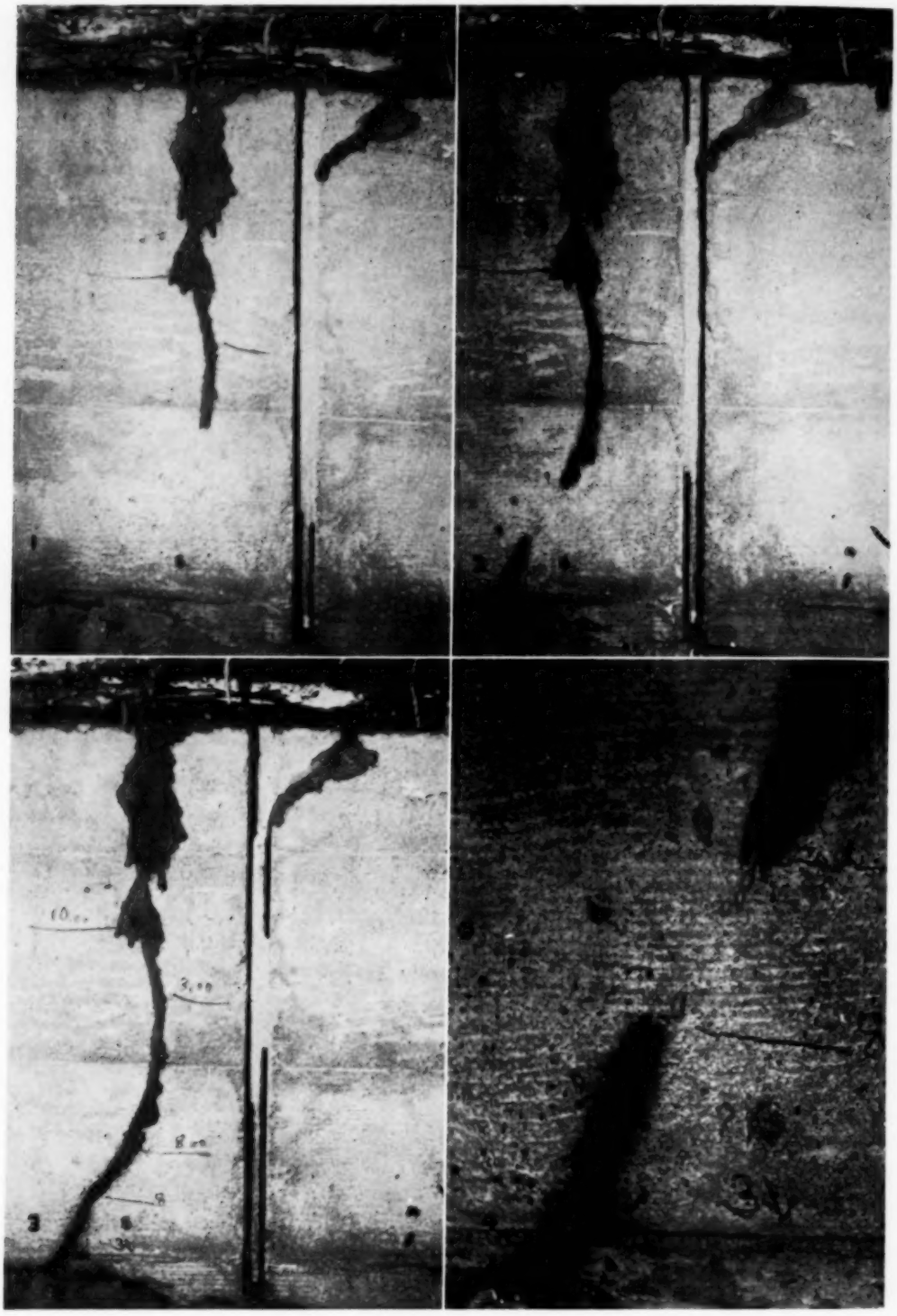


FIG. 2.—1. Termites which reached the soil start building along soil line. 2. Tube at soil line turns up to meet descending branch. 3. Completed tube. Note two additional tubes which are also constructed from both ends in corners of slot. 4. Closeup before tubes are joined. Lower portion of soil particles, upper portion of partially digested wood.

FIG. 3.—View of other tubes constructed in same manner. The one at the right was never completed to the soil.

infested wood to soil is common and easy to bring about experimentally. When heavily infested wood is placed on the pit wall the termites usually start to drop tubes within 24 hours. In the majority of cases the insects do not leave the open end of the runway for more than a few inches but build their shelter as they progress.

When the wood contains a large colony and moisture is needed quickly, however, the termites travel from wood to soil for relatively long periods without stopping to construct shelters. In one case a continuous column travelled back and forth from wood to soil for 10 hours before any attempt was made to erect a shelter tube.

Figures 1(3, 4) and 2(1, 2, 3, 4) show another case of unconventional termite activity. An infested apple log was placed on the pit wall. At the end of 24 hours many tubes were started at various points on the log. A few were constructed faster, apparently because of more concentrated activity at these points (Fig. 1(3)). Then a large number of termites left this tube and proceeded to the soil (Fig. 1(4)), where they commenced to build upward to meet the descending tube (Fig. 2(1, 2)). In about 24 hours more the two ends were brought together and joined (Fig. 2 (3)). A closeup at this point (Fig. 2 (4)), shows that the upper portion was constructed of partially digested wood or frass, while the lower portion, darker and granular in appearance, was composed of particles of soil.

In the meantime 5 other tubes were being constructed in the same manner (Fig. 3). Note that four of these were built in the corners of slots used to divide the pit. A seventh tube, started later than the others, was never completed and the termites did not leave the entrance to the shelter.

In our opinion these unusual activities occurred because the population was so large that the available moisture would have been dissipated before the runways to the soil could have been constructed in the usual way. When construction is carried on from both ends at once the time required to complete a tube is cut 50 per cent as there is room for twice as many termites to remain at work on the building operations.

There is some evidence that the termite colony sends out scouts or surveyors to determine the direction of the soil as there was definite selectivity in direction

FIG. 4.—General view of termite pit showing horizontal tube at soil line.

of tube-building. All the many tubes built down from wood placed on the pit wall were on the inside walls; none were attempted on the outside where the concrete floor of the laboratory would have been encountered (Fig. 4). Reversal of the log or variation of the light source did not affect this unfailing attraction to the inner walls and soil.

SUMMARY.—Analysis of termite attacks on buildings and results of laboratory experiments are in agreement with the reports of others that subterranean termites of the genus Reticulitermes rarely, if ever, construct tubes upward over foundation walls in the open. The cases which we have seen where such activity has occurred have resulted from excessively large colonies developed where there was wood in the ground adjacent to the foundation walls.

In dark, confined places such as basementless areas, Reticulitermes may build tubes over foundation walls in order to reach wood above. The probability or frequency of this activity depends upon such factors as relation of termite population to size of area, wood adjacent to the wall, and ventilation.

The majority of tubes seen on foundation walls in the East are constructed down and not up.

Under special conditions termites may reveal unusual types of activity such as travelling for many hours without tubes, constructing tubes from both ends, or building up many feet in the open.—1-7-41.

LITERATURE CITED

Light, S. F., *et al.*, 1934. Termites and Termite Control, p. 149. University of California Press.
Turner, N., and J. F. Townsend. 1939. Control of Termites in Buildings. Connecticut Agr. Expt. Sta. Circ. **134**: 4.

COTTON STATES BRANCH MEETING FOR 1942

Memphis, Tennessee, February 4, 5 and 6

Notes on the Hibernation of the Tobacco Flea Beetle and on the Parasite, *Microctonus epitricis* (Vier.)

C. B. Dominick[1] and George Wene, *Field Laboratory, Virginia Agricultural Experiment Station, Chatham*

The studies on the biology of the tobacco flea bettle, *Epitrix parrula* (F.), previously reported (Dominick 1939) have been continued. This paper gives the results of studies on the hibernation of the insects about tobacco stalks in the field and notes on the parasite *Microctonus epitricis* (Vier.).

Hibernation.—Migration studies (Dominick 1940) have shown that many of the tobacco flea beetles leave the tobacco field as harvesting progresses. Some beetles, however, continue to feed on suckers from old tobacco stalks until the plants are killed by frost. Many of these beetles hibernate within the tobacco field. Studies were made of the insects hibernating in the vicinity of the old stalks. In the spring of 1939 a field was selected for this study in which beetles had fed on the tobacco suckers until frost the preceding fall. All litter, consisting chiefly of leaves and grass, from around the base of a tobacco stalk was carefully gathered by hand. Then, with a trowel and whisk broom, the fine particles of plant debris and the loose soil were collected. This, along with the litter, was put in a battery jar and covered with a cloth to prevent the escape of the beetles. The soil from an area approximately 5 inches square was collected to a depth of 2 inches and put into another battery jar. Samples collected in this manner were placed in a warm room, and after several hours the beetles began to crawl out and were collected from the sides of the jars. In the spring of 1940 only the soil was collected for the studies. These soil samples were collected from four fields located in different localities and represented different soil types. No information was available on the abundance of the beetles the preceding fall.

The data indicate that more beetles passed the winter in the soil below the protective layer of vegetable debris than on the soil surface in the debris (Table 1). In the collection of December 20 the number of beetles which emerged was rather high; however, winter temperature had not been a factor in the mortality. On April 1, the following spring, 20 samples taken from this field yielded only 7 beetles. The winter, however, had been unusually severe with low temperatures during January and February of 1940.

In 1940 collections were made at intervals from April 1 until May 2 in four localities of Pittsylvania County representing different soil types. From a total of 100 samples, only 13 beetles were recovered. As stated above, the winter had been severe and winter mortality may have been responsible for the small number obtained.

Table 1.—The number of tobacco flea beetles found in debris and in the soil around the base of tobacco stalks, 1939.

Collection Date*		Number of Beetles Obtained From	
		Vegetable debris	Soil
March	21	0	7
	24	1	4
	27	0	10
April	3	1	18
	7	0	9
	21	0	4
December	20	2	41

* Fifteen samples on each date.

Winter Mortality Studies.—In the fall of 1938 cages 18 by 18 by 18 inches, made of wooden strips and covered with thin, unbleached muslin, were placed over natural woods litter along the edge of a wooded area. Beetles were captured and put in the cages on the dates indicated in table 2. The cages and their contents were left undisturbed during the winter and the following spring. With the coming of warm weather all active beetles were removed from the cages twice daily.

The beetles emerged from hibernation from March 21 until May 26, which was a period of 66 days. The percentage of beetles which survived the winter was rather low in all cages except one, and in that particular cage only 30 per cent of the beetles survived (Table 2). It is likely that under natural conditions the beetles

[1] Thanks are due Dr. C. F. W. Muesebeck for identifying *Microctonus epitricis* (Vier.)

Table 2.—The survival of the tobacco flea beetle under caged conditions during the winter of 1938–39.

DATE BEETLES WERE CAGED (1938)	NUMBER OF BEETLES CAGED	SURVIVAL (SPRING, 1939) PER CENT
October 4	1000	1.60
6	1000	1.70
7	1000	5.10
10	1000	3.90
12	1000	1.30
17	1000	4.30
26	200	30.00

would have fed longer in the fall and would have selected more favorable quarters for hibernation than was possible in the cages, with the result that the number surviving would have been greater.

PARASITISM STUDIES.—In 1940 studies were made in Pittsylvania County of the importance and distribution of *Microctonus epitricis* (Vier.), a parasite of the family Braconidae which attacks the tobacco flea bettle in the adult stage.

Tobacco flea beetles were collected from five localities in the county (Table 3). The collections were made at random in three to five large tobacco fields in each locality, 1,000 beetles generally being collected in each locality. The beetles from each locality were put in a lantern-globe cage which was covered at the top with white muslin. The cage had a cardboard base, and on the bottom was a section of black muslin and over this a section of black cheesecloth. A small tobacco leaf was provided as food each day for the beetles. The mature larva of *Microctonus epitricis* which has developed in the abdomen of the flea beetle and made its exit through the insect's vent, passes through the layer of cheesecloth and, within 6 to 10 hours, spins its cocoon between the two layers of cloth. Only one larva was seen to make its exit from a single beetle. The cages were examined daily for larvae and pupae of the parasite.

Table 3.—Parasitism of the tobacco flea beetle by *Microctonus epitricis* in different localities of Pittsylvania County during July and August 1940.

LOCALITY	COLLECTION DATE	NUMBER OF BEETLES	PER CENT PARASITISM
Chatham	July 22 to 26	1000	25.40
Dry Fork	26	1000	13.30
Climax	August 1	979	13.59
Danville	12	1000	7.00
Gretna	13	715	6.01
Chatham	19	1000	9.70
Dry Fork	20	1000	6.40
Climax	21	1000	9.50
Danville	23	800	13.00
Gretna	24	1000	9.00

In the first collections, which were made between July 22 and August 13 (Table 3), the parasitism varied from 6.01 per cent at Gretna to 25.4 per cent at Chatham. The parasitism at Dry Fork was 13.3 per cent, and at Climax 13.5 per cent; whereas at Danville it was only 7 per cent. In the second collections, which were made between August 19 and August 24 from the same localities, the parasitism varied from 6.4 per cent at Dry Fork to 13.0 per cent at Danville. The parasitism in the Chatham collection was 9.7 per cent; the Climax, 9.5 per cent, and the Gretna, 9.0 per cent.

SUMMARY.—More tobacco flea beetles were found in winter quarters in the soil around the base of tobacco stalks in old undisturbed tobacco fields then in vegetable covering above the soil surface. The percentages of beetles to survive the winter in cages were relatively low; however in one cage 30 per cent of the beetles survived. Parasitism of the tobacco flea beetle by *Microctonus epitricis* (Vier.), varied from 6.01 per cent to 25.4 per cent in different localities and at different times.—12–28–40.

LITERATURE CITED

Dominick, C. B. 1939. Notes on the tobacco flea beetle, *Epitrix parvula* (F.). JOUR. ECON. ENT. 32(4): 495–8.

Dominick, C. B. 1940. Migration of the tobacco flea beetle. JOUR. ECON. ENT. 33(3): 470–2.

Provision has also been made under the terminal inspection procedure for the enforcement of Minnesota's quarantine relating to the Alfalfa weevil and certain diseases of raspberry plants. Facilities for inspection have been provided at St. Paul.

The Tobacco Flea Beetle in Abandoned Plant Beds

C. B. Dominick, *Field Laboratory, Virginia Agricultural Experiment Station, Chatham*

The importance of tobacco plant beds as breeding quarters for the tobacco flea beetle, *Epitrix parvula* (F.), in the early season has been recognized. This paper is a report on studies of the insect and its control in abandoned plant beds during the seasons of 1938 to 1940, inclusive.

Insects in Plant Bed Soil.—During June and July of 1938 a study was made of the immature stages of the tobacco flea beetle in the soil of two abandoned tobacco plant beds. Records were also kept of the number of newly transformed adults found in these places. The procedure was as follows: An area 1 foot square was examined in a given plant bed on the dates indicated in table 1. The areas were selected at random and only one area was examined per plant bed on any date. The plants were first removed from the selected area and the soil was carefully shaken from their roots into a 10-quart bucket. Then all the soil to a depth of 2 inches was collected. The soil collected was taken to the laboratory, where it was first sifted through a 4-mesh screen to remove the roots and break up the soil particles. It was then segregated in small quantities and a record was made of the number and stage of the insects found. The soil was of a dark type owing to an abundance of organic matter, and the immature insects were easily found. Owing to the difficulty of observing the eggs because of their small size and the early stages of the larvae because of their habit of burrowing into the roots and stems of the plants, no record was obtained of these stages. Other methods, such as washing the soil through a series of different mesh screens and sifting the soil, were also used; but these methods required a greater length of time with little increase in accuracy.

In 1940 the procedure was the same, except that only one plant bed was used for the studies and two or three sections instead of one were examined on each date indicated in table 2. These studies were continued until October 18 in 1940, whereas they were discontinued on July 7 in 1938.

Results.—The results of the investigations during 1938 showed that the immature stages of the tobacco flea beetle were abundant in the soil of the two abandoned plant beds under observation throughout the month of June, the period of greatest abundance being between June 6 and June 10 (Table 1). In 1940 the insects were abundant on June 8 and most abundant on June 14, when 288 specimens were taken from 3 square feet of soil, although the season of 1940 was somewhat later than that of 1938. The results of the investigations indicate that the immature stages of the tobacco flea beetle occur in plant bed soils in the greatest abundance in June and July. In 1940, however, small numbers were also found until the studies were discontinued in October of that year

Table 1.—Stages of the tobacco flea beetle found in square-foot sections of plant bed area in two localities of Pittsylvania County, Virginia, 1938.

Date of Collection	Locality	Number of Insects*				
		Adults	Pupae	Prepupae	3d Instar larvae	Total
June 6	Dry Fork	3	19	27	19	68
7	Dry Fork	3	40	15	11	69
8	Chatham	2	31	10	10	53
9	Chatham	2	35	4	7	48
13	Dry Fork	1	26	3	2	32
14	Chatham	1	21	6	3	31
18	Dry Fork	1	26	6	3	36
25	Chatham	0	12	0	1	13
29	Dry Fork	0	12	3	2	17
July 5	Chatham	0	6	2	1	9
7	Dry Fork	0	2	0	0	2

* Found in 1 square foot of soil.

Table 2.—Stages of the tobacco flea beetle found in 1-square-foot sections of a tobacco plant bed at Dry Fork, Virginia, 1940.

Date of Collection		Square Feet Examined	Number of Insects				
			Adults	Pupae	Prepupae	3d Instar larvae	Total
June	8	3	2	48	28	27	105
	12	3	5	43	32	23	103
	14	3	6	138	55	89	288
	20	3	2	30	20	14	66
	26	3	4	22	23	22	71
July	12	3	1	4	2	8	15
	19	3	3	3	3	7	16
	26	2	0	3	3	5	11
August	5	2	0	5	3	3	11
	20	2	0	3	1	4	8
September	2	2	0	1	4	4	9
	13	2	0	2	8	1	11
	20	2	0	0	2	3	5
	27	2	0	10	0	0	10
October	4	2	0	2	1	2	5
	11	2	0	1	0	1	2
	18	2	2	3	0	0	5

(Table 2). The data indicate that the over wintered beetles deposit large numbers of eggs when not controlled, and under the ideal conditions for flea beetle development found in tobacco plant beds, these eggs develop into a large first brood of beetles.

MIGRATION FROM PLANT BED TO FIELD.—For this study a plant bed located in the edge of a wooded area about 200 feet from a tobacco field several acres in size was selected. On June 10, four adhesive screens of the type used by Dominick (1940) in studies on the migration of the adult beetles were placed facing the exposed side of the plant bed at intervals of 7.5 feet and at 8 feet from the border of the plant bed. They were left until August 15, at which time there were few beetles on the plants in the bed.

The data show that the emerging beetles were active from June 15 until the experiment was discontinued on August 15. The greatest activity occurred on July 8, although there was considerable activity during the period from June 15 to June 26. Figure 1 represents the total number of beetles captured on either side of the screens. It can be seen that by far the greater number of the insects were captured on the side of the screens facing the plant bed than were captured on the side facing the tobacco field. During the entire period 556 beetles were taken on the side of the screens facing the plant bed and only 96 on the side facing the tobacco field.

The beetles, upon emerging from the soil, feed for several days on the lower leaves of the small, shaded or dwarfed plants. Large numbers of the beetles were found feeding in this manner, and the riddled condition of the plants was noticeable during June and early July. After the beetles have fed for several days they leave the plant bed and move to a nearby tobacco field.

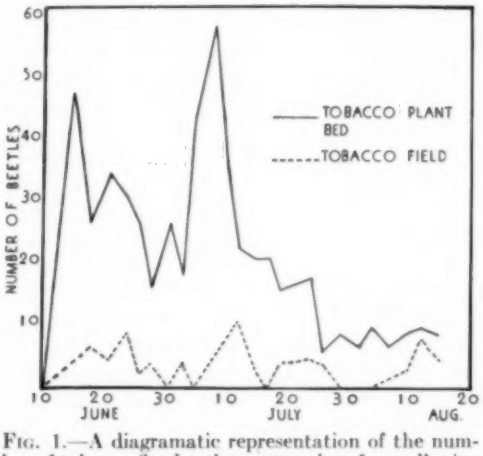


FIG. 1.—A diagramatic representation of the number of tobacco flea beetles captured on four adhesive screens located along the edge of a tobacco plant bed facing a tobacco field.

EXPERIMENTS ON SOIL TREATMENT.—An experiment was conducted to obtain information on the effectiveness of dichlorethyl ether against the larvae and pupae of the tobacco flea beetle under field

conditions. Emergence cages, each 1 yard square and 6 inches high, were used in these studies. Six cages placed on the ground within a plant bed area were used each year, and owing to the light infestation in the beds, 75 first brood beetles were added to each cage on June 6 to 9 in 1939 and on June 21 in 1940. The beetles were allowed to remain in the cages for a period of 12 days in order that oviposition might occur. The cages were then removed and the plants thoroughly dusted with a dust containing 1 per cent rotenone in order to destroy the adult beetles and prevent further infestation. The cages were replaced and the dichlorethyl ether treatments were applied on July 4 in 1939 and on July 15 in 1940. It was assumed that on these dates a large number of the insects were in the late immature stages, laboratory studies having shown that the life cycle was about 28 days at the time of the experiments.

In the tests one gallon of solution of dichlorethyl ether at the concentrations shown in table 3 was used for each square yard of soil. The solution was sprayed gradually on the areas to be treated and allowed to soak into the soil without runoff so as to give an even distribution. The cages were left off the treated sections for 3 days and were then replaced. Examinations were made every 2 days for emerging beetles. The results of these studies are given in table 3. Dichlorethyl ether in water at a strength as low as 10 cc. per gallon of water apparently gave some kill of the immature stages of the tobacco flea beetle. When applied at a concentration of 30 cc. in 1 gallon of water a high mortality occurred, although a complete kill did not result in either test. Where 30 cc. of dichlorethyl ether were used to the gallon of water in 1939, no beetles emerged until after 11 days; and where 30 cc. of dichlorethyl ether to 1 gallon of water was used in 1940, none emerged until after 20 days. This indicates that the late stages of the insect, which are free in the soil, are more susceptible to the treatments than the earlier stages, which feed largely within the roots or even within tender stems above the ground. The treatments caused some injury to the roots and stems but did not kill the plants.

Table 3.—Results of field experiments with dichlorethyl ether applied as a spray to the soil for the control of the tobacco flea beetle, Chatham, Virginia, 1939 and 1940.

Experiments in 1939		Experiments in 1940	
Dichlorethyl ether (cc. per gal.)*	Beetles emerging (Number)	Dichlorethyl ether (cc. per gal.)*	Beetles emerging (Number)
10	29	15	21
15	16	15	13
20	5	30	2
25	4	30	6
30	3	Check (untreated)	106
Check (untreated)	229	Check (untreated)	139

* Applied to 1 square yard of soil.

CULTURAL PRACTICES.—Studies were made in four plant beds of 100 square yards each which the growers had treated as follows: All the plants were removed from the soil on June 10, 1940, and their roots exposed to the sun outside the beds; the soil was thoroughly plowed and disked and each area was seeded to garden crops. On June 16, at which time the insects were abundant in the abandoned plant bed (Table 2), soil samples were taken and examined. No insects were found. Small sections of plant beds located near the laboratory were also treated in like manner with similar results.

DISCUSSION.—From the data obtained by examining square-foot sections of plant bed soil and from the migration experiment, it is evident that tobacco plant beds play an important role in building up the tobacco flea beetle population in the field. The destruction of plant beds immediately after transplanting is completed, therefore, should result in a reduction in the infestation of the young plants in the field. Treating the abandoned plant beds with dichlorethyl ether at the rate of 30 cc. in 1 gallon of water per square yard of plant bed area immediately after field transplanting has been completed gave satisfactory results. This method, however, is not practical for the average grower owing to the additional expense and labor involved; apparently cultural practices will give as good results. When dichlorethyl ether is used, it is necessary to destroy the plants before the treatment is made or a week or 10 days later to prevent further breeding and emergence of the insects not destroyed by the soil treatment.

SUMMARY.—The importance of tobacco plant beds as breeding places for the tobacco flea beetle was studied during the

years 1938 to 1940, inclusive. It was found that the immature stages of the insect were most abundant in soil samples taken from abandoned plant beds during the first half of June, although breeding continued until the investigations were discontinued in October. It was demonstrated that after the beetles emerge in abandoned plant beds and have fed for several days they migrate to nearby tobacco fields. Soil treatment with dichlorethyl ether and cultural treatment of the plant bed after transplanting has been completed gave satisfactory results as a control.—12-28-40.

LITERATURE CITED

Dominick, C. B. 1940. Migration of the tobacco flea beetle. JOUR. ECON. ENT. **33**(3): 470–2.

A Progress Report on Tomato Fruit Worm Studies[1]

J. G. WATTS, *South Carolina Agricultural Experiment Station, Blackville*

Field experiments on the control of *Heliothis armigera* (Hbn.) were begun at the Edisto Experiment Station in the spring of 1940, where three phases of control with insecticides were studies:[2] Comparison of insecticidal dusts and baits, comparison of insecticidal sprays, and comparison of diluents.

Each treatment was applied to four replicate plots of tomatoes, arranged in a randomized block. The plots were 30 feet long by 20 feet wide and comprised 4 rows, 5 feet apart, with 10 plants per row. At this rate there were approximately 2,904 plants per acre.

The dust components were mixed in a power mixer and applied with rotary hand guns to both sides of each row. The baits were mixed in a power mixer and, in a dry condition, were scattered as uniformly as possible over the tomato foliage by hand. Sprays were mixed in the tank of a wheelbarrow sprayer with which they were applied at about 200 pounds pressure. The rates of application were, for dusts 15 to 25 pounds per acre, for baits 40 to 70 pounds, and for sprays 65 to 130 gallons, increasing in each case with the size of the plants.

An application of the insecticides was made at weekly intervals except when interrupted by rainy weather. Applications therefore were made on the following dates: May 21 (rain within 12 hours), May 25 (rain within 36 hours), June 1, 8, 15, and 20. At the time of the first application fruits had just begun to set and the plants had a spread of approximately 12 inches. Newly hatched larvae were first found on May 16, oviposition probably having commenced about May 10.

The data were taken by examining all fruits from each plot. Examinations were made in the field beside the plot stake where tomatoes had been placed after picking. At each picking, in addition to the marketable tomatoes, all observed wormy fruits, as well as all those attacked by disease were gathered. If for any reason the regular pickings were delayed a special picking of the plots was made for wormy and diseased fruits. In this manner those starting to decay were examined before they had broken down beyond recognition of the cause.

SEASONAL DISTRIBUTION OF DAMAGE.—The seasonal distribution of fruit worm damage on early tomatoes in the South has certain practical aspects which are important in profitable tomato production. The usual practice of tomato harvest in South Carolina is to pick and ship "green wraps" as long as returns are profitable. Thereafter, ripe tomatoes are sold to local canneries. The distribution of fruit worm damage on the 1940 crop is shown in figure 1, from which it is seen that approximately 95 per cent of the damage occurred prior to and during the "green wrap" picking season. Because of the much greater unit price of green tomatoes, effective control of the fruit worm on the first several pickings of the spring tomato crop becomes of outstanding importance to growers. Fruit worm damage is relatively negligible on that portion of the crop usually sold for canning, consequently control measures are not necessary. A pronounced

[1] Technical contribution No. 79 South Carolina Experiment Station, Clemson, S. C.

[2] Other phases of the tomato fruit worm problem are being studied at Clemson, S. C., by Messrs F. Sherman, O. L. Cartwright and W. M. Upholt of the Entomology Department, S. C. Agricultural Experiment Station.

decline in fruit worm damage to early tomatoes occurred almost immediately following the silking of nearby corn, the latter being the preferred host.

Since the fruit worm damage was so definitely concentrated on the earlier portion of the crop, only the data from the first six pickings were used in calculating the effectiveness of the various treatments. These included all of the "green wrap" pickings but none of the "ripe" pickings.

DUSTS AND BAITS.—Natural and synthetic cryolite were each used at 30, 50, and 90 per cent strengths, while basic copper, calcium, and lead arsenates were used at 10, 50, and 100 per cent strength. Cubé root with a rotenone content of 5 per cent was diluted to give a mixture containing 1 per cent rotenone. The cryolites and arsenates were diluted with 10 per cent cotton seed meal and kaolin to

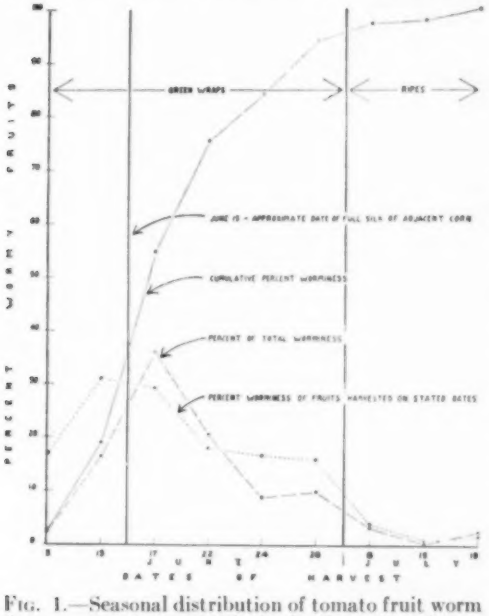


FIG. 1.—Seasonal distribution of tomato fruit worm damage on 12 untreated check plots of early tomatoes. Edisto Experiment Station, Blackville, S. C., 1940.

make 100 per cent, except, of course, where the arsenates were used undiluted. The rotenone was diluted with 4 per cent cotton seed oil and kaolin to make 100 per cent. There was little difference in the effectiveness of 30 and 50 per cent cryolite (Fig. 3), but the 90 per cent strength was definitely superior. There was a tendency for the arsenates to be slightly more effective than the cryolites at 50 per cent

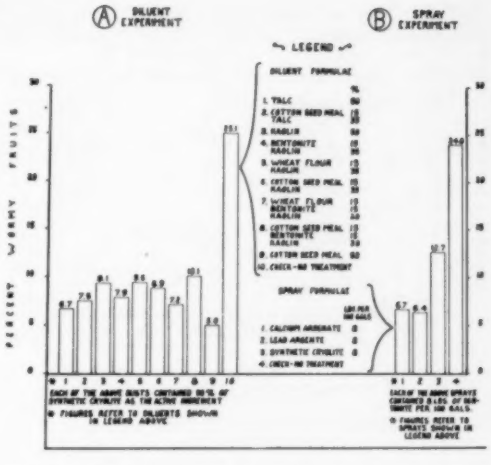


FIG. 2.—Two tomato fruit worm experiments A—Evaluating dust diluents. B—Evaluating sprays. Edisto Experiment Station, Blackville, S. C., 1940. Data were taken from six pickings of "green wrap" tomatoes.

strength, but at 90 per cent the tendency was for the cryolites to be slightly more effective than the arsenates at 100 per cent. It is noted (Fig. 3) that basic copper arsenate at 50 per cent was more effective than the same chemical undiluted. This is explained by the fact that in the undiluted form this arsenical had very poor dusting quality which most likely resulted in poor coverage, while at the 50 per cent strength the kaolin, supplemented with cotton seed meal, produced a mixture with good dusting quality. Rotenone was the only insecticide used which gave no control. There was approximately 30 per cent more wormy fruit (Fig. 3) on the plots receiving rotenone than on the untreated check plots. This in all probability was due to the fact that *Phlegethontius sexta* Johanssen and *P. quinquemaculata* Howarth caused extensive defoliation of the check plots, very likely making these plots less attractive to the fruit worm moths for oviposition; however, on the rotenone plots the two horn worms were controlled to quite a degree, leaving these more attractive to the fruit worm moths for oviposition. If this is the case, the infestation in the rotenone plots was perhaps nearer the actual field infestation than was that on the untreated check plots.

Synthetic cryolite, calcium and lead arsenates were each used at 10 per cent strengths with 90 per cent of corn meal as a bait. There was little difference in the

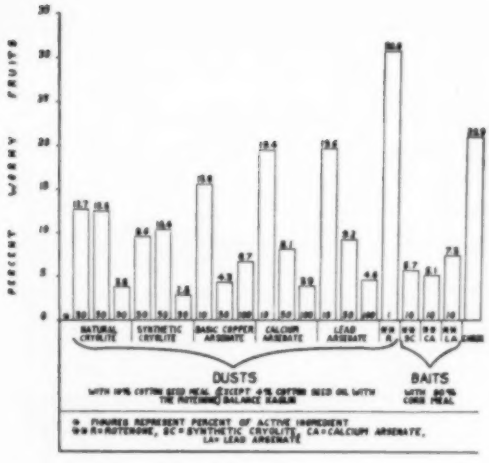


FIG. 3.—A comparison of several insecticides some of which were used both as dusts and baits, at various dilutions in controlling the tomato fruit worm, Edisto Experiment Station, Blackville, S. C., 1940. Data were taken from six pickings of "green wrap" tomatoes.

effectiveness of these mixtures (Fig. 3), a relatively high degree of control resulting in each case. There was a marked superiority of the bait mixtures over dusts with an equal concentration of the active ingredient, and these were slightly more effective than dusts with 50 per cent of the active ingredient.

SPRAYS.—Calcium arsenate, lead arsenate and synthetic cryolite were each used as a spray at 8 pounds per 100 gallons of water containing 8 pounds of bentonite. The two arsenates were about equally effective and were superior to synthetic cryolite (Fig. 2 B).

DUST DILUENTS.—In selecting the inert carrier for an insecticide at least four objectives are sought. The carrier must have good dusting quality so that a uniform, enveloping cloud of dust will be formed. It must transport the active ingredient from the dust gun to the plant without separating them from each other. It should wet easily so that it will disperse uniformly in droplets of dew upon the plant and not ball up in a ring around the periphery of the drop. Finally, it should possess a moderate to high degree of plasticity so that after the dew has dried away the active ingredient will adhere to the plant surface, thus withstanding light or moderate showers of rain. The diluents employed were selected because of their superiority in one or more of the above points and their acceptibility in the remaining points as determined in preliminary laboratory tests. It should be mentioned here that kaolin and talc from different sources vary considerably in their physical properties. In these tests Loomis talc and a rubber type kaolin, mined in South Carolina, were employed.

In an experiment comparing nine diluent formulae, 50 per cent of natural cryolite comprised the active ingredient. Though the differences in per cent wormy fruits resulting (Fig. 2, A) from the various diluent combinations were not especially striking, there was a tendency for mixtures possessing superior dusting quality and moderately good adhesiveness to perform better than those with superior adhesiveness and moderate dusting quality. The greatest reduction in worminess resulted where screened cotton seed meal comprised the diluent. This mixture had exceptionally good dusting quality as well as moderately good adhesive properties. The talc had equally good dusting quality but was somewhat less adhesive. The dusting and plastic properties of kaolin were only moderately good, but extensive use was made of it because of its cheapness and availability. The adhesiveness of bentonite was superior to that of any of the diluents tested but it is very heavy and cannot be used too freely in dust mixtures. Small quantities of wheat flour had a sort of lubricating effect and a'so increased adhesiveness somewhat. It would be expected that at a lower concentration of the active ingredient the difference in the performance of the various diluents would be greater.

RESIDUE.—On the early tomato crop in South Carolina it will usually be impractical to arrange a schedule for fruit worm control which will permit any interval between the last application of the insecticide and the first picking. As a matter of fact, under the conditions of these experiments a period of only two weeks elapsed between the first application of the insecticide and the first picking of green tomatoes, and there were three pickings before the last application was made. In view of these unusual circumstances, analyses were made for arsenic, lead and fluorine on samples of tomatoes from plots receiving the respective chemicals. In order that the most extreme conditions would be tested, the samples were taken the day following

Table 1.—Arsenical residue, expressed as As_2O_3, and lead residue, expressed as metallic lead, per lb. of tomato fruit, taken from field plots receiving different dusts, baits, and sprays. Edisto Experiment Station, Blackville, S. C.—1940.[1]

Insecticide Mixture		Field Sample—Unwiped			Field Sample—Wiped[2]		
		Wt. in gms.	Grains As_2O_3 per lb.	Grains Pb[3] per lb.	Wt. in gms.	Grains As_2O_3 per lb.	Grains Pb per lb.
Basic copper arsenate Cotton seed meal Kaolin	10% 10% 80%	2223.8	0.00122		2019.5	0.00127	
Basic copper arsenate Cotton seed meal Kaolin	50% 10% 40%	2203.7	0.00139		2078.5	0.021	
Basic copper arsenate	100%	2187.3	0.00845		2129.4	0.0031	
Calcium arsenate Cotton seed meal Kaolin	10% 10% 80%	2063.2	0.0010		1101.6	0.00031	
Calcium arsenate Cotton seed meal Kaolin	50% 10% 40%	2083.0	0.0025		1991.4	0.00114	
Calcium arsenate	100%	1988.9	0.0088		4146.4	0.00180	
Calcium arsenate Corn meal	10% 90%	2130.7	0.0082		1888.1	0.00145	
Lead arsenate Corn meal	10% 90%	1705.4	0.0043		2064.8	0.00247	
Lead arsenate Cotton seed meal Kaolin	10% 10% 80%	2034.9	0.0008	.00167	1776.5	0.0014	.00293
Lead arsenate Cotton seed meal Kaolin	50% 10% 40%	2091.5	0.0038	.0080	2105.8	0.0030	.00628
Lead arsenate	100%	2054.2	0.0088	.0184	1556.9	0.0073	.0153
Calcium arsenate Bentonite Water	8 lbs. 8 lbs. 100 gals.	1675.9	*0.032*[4]		2287.8	0.0129	
Lead arsenate Bentonite Water	8 lbs. 8 lbs. 100 gals.	2091.3	0.011	.023	2121.4	0.0060	.0126

[1] Samples were taken after the six applications of insecticides noted in the third paragraph of the text. The last application was made on June 20 and the samples were taken on June 21 with no intervening rain.
[2] Wiped with a piece of dry cheese cloth.
[3] Calculated from As_2O_3 analysis.
[4] Only samples on which arsenic or lead exceeded or closely approached the tolerance (0.025 grains of arsenic trioxide and 0.05 grains of lead per pound of fruit) set by the Federal Food, Drug and Cosmetic Act revision of August 10, 1940.

the last application of insecticides and there was no intervening rain. Analysis[1] of the field samples showed only one to exceed (Tables 1 and 2) the As_2O_3 tolerance of 0.025 grains, none to exceed the lead tolerance of 0.05 grains, and only three to exceed the tolerance of 0.02 grains of fluorine per pound of fruit. In another group of samples where each fruit was wiped with a piece of dry cheese cloth, none of the samples exceeded the tolerance.

[1] Analyses were made by Dr. H. J. Webb, Department of Fertilizer and Analysis, Clemson, S. C.

SUMMARY.—Results of tomato fruit worm control experiments in South Carolina in 1940 are presented. The seasonal distribution of the insect damage on un-

Table 2.—Fluorine residue on tomato fruits taken from field plots receiving different dusts, baits, and sprays. Edisto Experiment Station, Blackville, S. C.—1940.[1]

Insecticide Formulae		Field Sample—Not Wiped		Field Sample—Wiped[2]	
		Wt. in gms.	Fluorine grains per lb.	Wt. in gms.	Fluorine grains per lb.
Natural cryolite	30%				
Cotton seed meal	10				
Kaolin	60	1971.8	0.00426	2076.4	0.00212
Natural cryolite	50%				
Cotton seed meal	10				
Kaolin	40	960.2	0.00509	1793.1	0.00175
Natural cryolite	90%				
Cotton seed meal	10	926.9	0.0139	946.0	0.00569
Synthetic cryolite	30%				
Cotton seed meal	10				
Kaolin	60	963.2	0.00356	840.9	0.00190
Synthetic cryolite	50%				
Cotton seed meal	10				
Kaolin	40	1989.9	0.01847[4]	756.9	0.00212
Synthetic cryolite	90%				
Cotton seed meal	10	503.5	*0.03138*[3]	588.7	0.01152
Synthetic cryolite	10%				
Corn meal	90	773.6	0.01102	1559.9	0.00499
Natural cryolite	50%				
Talc	50	2122.2	0.01760[4]	1887.3	0.00574
Natural cryolite	50%				
Cotton seed meal	15				
Talc	35	818.0	0.01880[4]	762.5	0.01724[4]
Natural cryolite	50%				
Kaolin	50	1938.0	0.00922	218.7	0.00368
Natural cryolite	50%				
Bentonite	15				
Kaolin	35	2085.9	0.01936[4]	1747.6	0.00539
Natural cryolite	50%				
Wheat flour	15				
Kaolin	35	1146.8	0.01704[4]	876.9	0.00829
Natural cryolite	50%				
Cotton seed meal	15				
Kaolin	35	2145.2	0.00677	1163.4	0.00346
Natural cryolite	50%				
Wheat flour	15				
Bentonite	15				
Kaolin	20	1662.6	*0.03629*[3]	402.0	0.00464
Natural cryolite	50%				
Cotton seed meal	15				
Bentonite	15				
Kaolin	20	1295.3	0.00513	1732.4	0.00367
Natural cryolite	50%				
Cotton seed meal	50	1360.1	*0.03207*[3]	2106.1	0.00365
Synthetic cryolite	8 lbs.				
Bentonite	8 lbs.				
Water	100 gals.	2130.5	0.01377	1416.1	0.00577

[1] Samples were taken after the six applications of insecticides noted in the third paragraph of the text. The last application was made on June 20 and the samples were taken on June 21 with no intervening rain.

[2] Wiped with piece of dry cheese cloth.

[3] Samples on which fluorine exceeded the tolerance (0.02 grains of fluorine per pound of fruit) set by the Federal Food, Drug and Cosmetic Act, Revision of Aug. 10, 1940.

[4] Samples approaching the tolerance.

treated tomatoes is shown. Insecticides were applied in the form of dusts, baits and sprays. Because of the difference in price, more economical control was obtained with calcium arsenate than with other arsenicals or cryolite. Corn meal baits are particularly promising because of the relatively high degree of control which they produced, their low cost, and their ease of application. Data is presented, on different dust diluents. Poisonous residue on the fruits was not a serious problem as was shown by analyses of samples of tomatoes receiving the various treatments of both natural and synthetic cryolite with different diluents.—12-28-40.

Sand-Arsenical Mixtures for Controlling White Grubs and Their Effect upon the Growth of Strawberries

T. W. KERR, JR., *Cornell University, Ithaca, New York*

During the course of previous investigations (Kerr 1939, 1940) it was observed that strawberry plants treated with sand-arsenical mixtures to control white grubs, *Phyllophaga* spp. appeared to be retarded in growth. The purpose of this investigation was to determine the effect of sand-arsenical mixtures on the growth activities of four varieties of strawberries.

MATERIALS AND METHODS.—The sand-arsenical mixtures used in the experiments were prepared according to the method described by the author (Kerr, 1940) in which one pound of arsenical was mixed in a barrel mixer, with 10, 20, and 50 pounds of air-dry sand respectively. The mixtures used were lead arsenate-sand, 1–10, 1–20, 1–50; magnesium arsenate-sand 1–10, 1–20, 1–50; and lead arsenate-sand 1–20 plus "starter solution." Sand, alone, and starter solution, alone, were also used. The "starter solution," proposed by Sayre (1939), was prepared by adding 50 grams of *Ammo-Phos* (analysis 11–48–0) and 25 grams of a commercial grade of nitrate of potash to 5 gallons of water. Application of the root treatments was made at the time when the plants were set out in the field. Where the dry, sand-arsenical mixtures, and the sand, alone, treatment were used, one handful of material (approximately 1.5 ounces) was scattered into the hole previous to placing the plant roots therein. When starter solution alone was used, one pint of the solution was poured into the hole made in the moist soil previous to planting the plant. In the case of the lead arsenate-sand 1–20 plus starter solution treatment, one pint of the starter solution was poured into the hole, and after the soil had absorbed all or part of the solution, approximately 1.5 ounces of the sand-arsenical mixture was scattered into the hole.

Plants of the four strawberry varieties used in the investigation were obtained from different sources. Plants of the varities Dorsett and Premier were obtained from fields in the immediate neighborhood of the experimental planting, while plants of the varieties Catskill and Mastodon were secured from Salisbury, Maryland.

The Catskill and Mastodon plants were dug early in March, shipped to and received by the writer on March 22, at which time they were placed in cold storage where the temperature approximated 32° F. On April 29, the plants of both varieties were removed from cold storage, and held at a temperature approximating 45° F. until planted in the field on May 1 and 2. Plants of the variety Premier were dug on April 30, held in cold storage at a temperature approximating 45° F. and planted on May 2, while those of the variety Dorsett were dug on May 3, stored at a corresponding temperature and planted in the field on May 6.

The condition of the varieties Dorsett and Premier was excellent, the crowns and roots of the plants presenting a healthy appearance and showing no symptoms of winter injury. Only those plants of good size, and of good crown and root development were used. On the other hand, plants of the varieties Catskill and Mastodon, while appearing healthy and showing no symptoms of winter injury, were small in size and had poor root and crown development. Therefore, in considering the abovementioned facts on the condition of the plants of the four varieties, it is apparent that no comparisons of the growth activities obtained as a result of these experi-

ments can be made between varieties. In western New York the Premier is considered an early, commercial variety; Catskill, a mid-season, commercial variety; Dorsett, a home garden variety; and Mastodon, an everbearing, or fall-bearing variety.

The planting was approximately three-fourths acre in area and was located on a field the soil type of which is designated by Howe *et al.* (1931) as Chenango silt loam. From the spring of 1929 to the late summer of 1938 the land contained a red raspberry planting. After the final raspberry harvest during the summer of 1938 the planting was plowed under and rye sown as a cover crop. In the spring of 1939, 10 tons of manure plus 1,000 pounds of superphosphate per acre was applied to the land previous to planting grape cuttings. The grape cuttings were removed in the fall of 1939 and rye sown as a cover crop.

The experimental planting consisted of 48 rows, each 200 feet in length and was randomized to provide four replicates each containing 48 rows, 50 feet long. The four strawberry varieties were randomized according to the Latin square scheme, each variety in each replicate containing a group of 12 treatments, nine of which were treated rows and three of which were check rows. The treatments were divided into four group-units of three treatments each. Since there were only three check rows provided, one group-unit was without a check row. The group-units were then randomized, according to the Latin square arrangement, randomization being among group-units in each replicate and among group-units of the entire planting. The distance between plants in the row and the distance between rows was 24 and 42 inches respectively for all varieties used. As was anticipated, relatively few *Phyllophaga* spp. were present in the soil occupied by the planting.

The matted row system of training the strawberries was employed. Blossoms were removed, whenever they appeared, from all varieties except Mastodon. In the case of this variety blossoms were removed until July 13, after which time further blossom removal was not practiced.

Beginning on May 23 inspections were made at 10-day intervals to determine (1) natural plant mortality, plant mortality due to insecticidal injury, and mortality due to a combination of these two factors; (2) mortality of plants due to white grub attack; and (3) rate and amount of runner production. At the time of each inspection dead plants were removed, classified, and recorded, while identifying wooden stakes were put in their places. By August 11, growth of plants had progressed to the point where further counts of runner production was impossible. Therefore, this aspect of the experiment was abandoned at that time. The analysis of variance was applied to the data on runner production of all varieties to determine the least difference for the date of maximum runner production of the untreated plants and for the final date during which data was recorded for all varieties except Mastodon.

RESULTS.—In the entire planting plant losses due to white grub attack, insecticidal mortality or natural mortality were extremely small, 1.66 per cent being attributed to white grub attack and .5 per cent being attributed to insecticidal or to natural mortality.

The data on runner production of the four varieties are presented in table 1. In the variety Catskill runners had appeared on the plants of the check, lead arsenate-sand 1–20 plus starter solution, starter solution, and sand alone treatments by June 12. By June 22 runners appeared on plants of all other treatments, except those of lead arsenate-sand 1–10, the plants of which first produced runners during the 10-day period June 22 to July 2. Among most of the sand-arsenical treatments, it was found that the more concentrated the mixture, the greater the retarding effect during the early part of the growing season. However, Catskill plants treated with magnesium arsenate-sand 1–50 proved to be an exception to the above statement for runner production of those plants treated with such a low concentration was less than that of either of the higher magnesium arsenate concentrations of 1–10 or 1–20.

On August 11, when counts of runner production were discontinued, it was found that the average number of runners produced per parent Catskill plant was greatest for the treatment of sand, alone (Fig. 1). Plants treated with starter solution, and untreated plants were close behind the sand alone treatment in the mat-

ter of runner production. Untreated Catskill plants reached the peak of runner production by August 1. It is evident from table 1 that those Catskill plants treated with magnesium arsenate-sand 1–10 and 1–50, and lead arsenate-sand 1–10 had produced significantly fewer runners per parent plant by August 1 and August 11 than did the plants of the three check treatments.

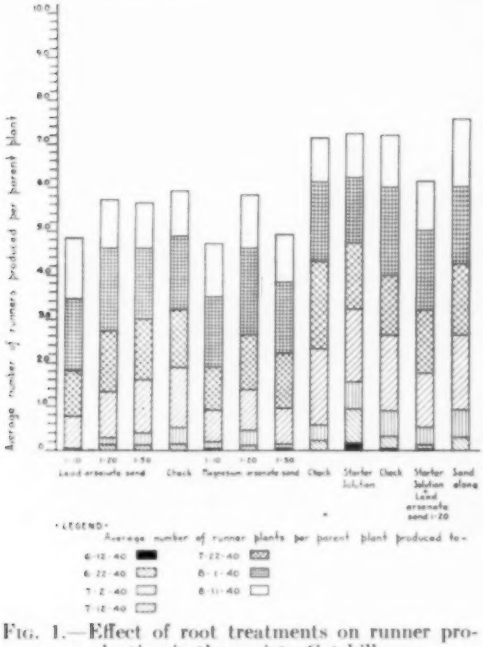


FIG. 1.—Effect of root treatments on runner production in the variety Catskill.

During the 10-day period June 2 to June 12 runners appeared on Premier plants of all treatments except those of magnesium arsenate-sand 1–10 and 1–50. Runners appeared on plants of these two treatments some time between June 12 and June 22. Here again, in the variety Premier, we find that growth activities, as measured by runner production, were retarded during the early part of the growing season by the application of sand-arsenical mixtures. Also, during the early part of the season, the more concentrated the sand-arsenical mixture, the greater the reduction in growth (Fig. 3). Untreated Premier plants reached the maximum of runner production by July 12. Those plants treated with starter solution had produced significantly more runners per parent plant than did the plants of all other treatments by July 12 and August

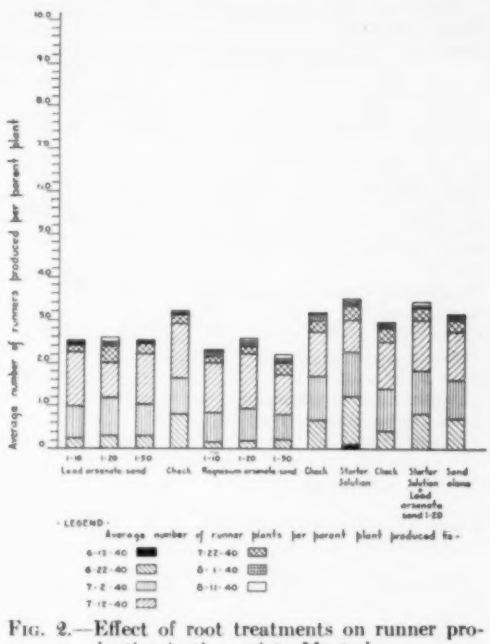


FIG. 2.—Effect of root treatments on runner production in the variety Mastodon.

11, while there were no significant differences in the average number of runners produced per parent plant between the average of the three check treatments and plants treated with sand-arsenical mixtures.

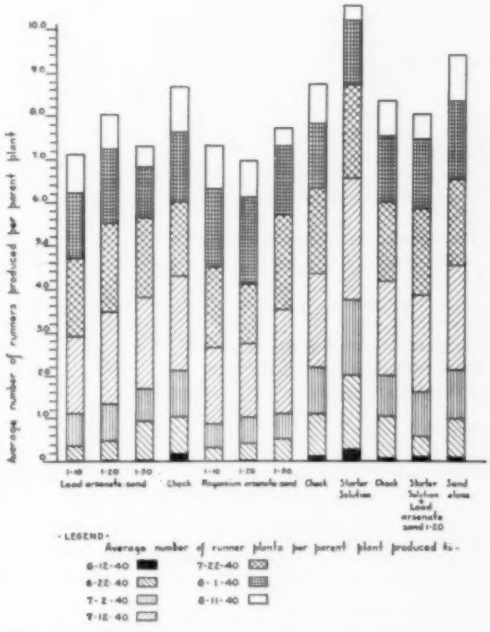


FIG. 3.—Effect of root treatments on runner production in the variety Premier.

Table 1.—Runner production of four varieties of strawberries under treatments indicated, Brant, New York, 1940.

Treatment	No. of Parent Plants	Average No. of Runners per Parent Plant Produced to						
		6-12-40	6-22-40	7-2-40	7-12-40	7-22-40	8-1-40	8-11-40
Variety Catskill								
Lead arsenate-sand, 1–50	96		0.114	0.395	1.604	3.083	4.614	5.656
Check	97	0.010	0.135	0.500	1.905	3.202	4.924	5.912
Magnesium arsenate-sand, 1–10	99		0.030	0.202	0.888	1.919	3.571	4.752
Lead arsenate-sand, 1–10	103			0.097	0.782	1.831	3.445	4.811
Check	102	0.009	0.215	0.588	2.376	4.290	6.131	7.173
Magnesium arsenate-sand, 1–20	101		0.099	0.435	1.376	2.663	4.630	5.830
Sand, alone	99	0.010	0.343	0.939	2.646	4.282	6.072	7.552
Check	101	0.019	0.326	0.891	2.613	4.049	6.090	7.200
Lead arsenate-sand, 1–20	101		0.109	0.287	1.346	2.742	4.650	5.780
Starter Solution	102	0.176	0.931	1.588	3.235	4.755	6.235	7.225
Magnesium arsenate-sand, 1–50	103		0.009	0.165	0.951	2.215	3.888	4.939
Lead arsenate-sand, 1–20 plus Starter Solution	99	0.010	0.131	0.515	1.777	3.272	5.131	6.181
Average of 3 checks		.013	.227	.662	2.306	3.861	5.735	6.785
Least difference at odds of 99:1		—	—	—	—	—	±1.654	±1.642
Variety Premier								
Lead arsenate-sand, 1–50	100	0.070	0.920	1.680	3.890	5.670	6.820	7.330
Check	100	0.160	1.040	2.120	4.260	6.080	7.620	8.666
Magnesium arsenate-sand, 1–10	102	0.000	0.323	0.863	2.637	4.500	6.294	7.333
Lead arsenate-sand, 1–10	99	0.040	0.387	1.153	2.969	4.755	6.265	7.112
Check	102	0.137	1.068	2.166	4.362	6.294	7.854	8.739
Magnesium arsenate-sand, 1–20	100	0.020	0.420	1.010	2.690	4.120	6.115	6.968
Sand, alone	99	0.091	0.949	2.141	4.495	6.551	8.347	9.387
Check	100	0.050	1.030	2.040	4.150	5.980	7.540	8.383
Lead arsenate-sand, 1–20	100	0.010	0.460	1.330	3.470	5.480	7.250	8.070
Starter Solution	98	0.265	2.040	3.765	6.571	8.724	10.112	10.510
Magnesium arsenate-sand, 1–50	100	0.000	0.500	1.060	3.515	5.737	7.333	7.727
Lead arsenate-sand, 1–20 plus Starter Solution	102	0.049	0.584	1.600	3.860	5.820	7.450	8.020
Average of 3 checks		.115	1.046	2.109	4.258	6.119	7.669	8.595
Least difference at odds of 99:1		—	—	—	±1.785	—	—	±1.934
Variety Dorsett								
Lead arsenate-sand, 1–50	102		0.019	0.147	1.465	3.445	4.990	5.410
Check	103		0.147	0.509	2.735	5.208	6.806	7.193
Magnesium arsenate-sand, 1–10	103		0.009	0.038	0.902	2.715	4.470	4.911
Lead arsenate-sand, 1–10	99		0.021	0.118	0.903	2.489	4.304	4.771
Check	102		0.039	0.465	2.584	4.564	6.296	6.645
Magnesium arsenate-sand, 1–20	101		0.010	0.089	0.960	2.227	3.811	4.287
Sand, alone	102		0.117	0.686	2.794	4.902	6.225	6.539
Check	101		0.109	0.802	2.782	4.980	6.450	6.850
Lead arsenate-sand, 1–20	100		0.010	0.100	1.340	3.380	4.940	5.222
Starter Solution	102		0.598	1.617	4.190	6.460	8.080	8.438
Magnesium arsenate-sand, 1–50	101		0.010	0.118	1.109	3.010	4.752	5.062
Lead arsenate-sand, 1–20 plus Starter Solution	102		0.050	0.293	1.798	3.818	5.434	5.676
Average of 3 checks			.098	.592	2.700	4.917	6.516	6.898
Least difference at odds of 99:1			—	—	—	±1.744	—	±1.907
Variety Mastodon								
Lead arsenate-sand, 1–50	98		0.296	1.102	2.265	2.469	2.489	2.530
Check	98	0.010	0.793	1.659	2.897	3.144	3.154	3.195
Magnesium arsenate-sand, 1–10	97		0.154	0.824	1.989	2.185	2.237	2.299
Lead arsenate-sand, 1–10	102		0.245	0.970	2.215	2.431	2.480	2.509
Check	97		0.656	1.666	2.718	3.020	3.114	3.135
Magnesium arsenate-sand, 1–20	100		0.181	0.939	2.262	2.444	2.520	2.540
Sand, alone	102		0.683	1.633	2.712	3.039	3.118	3.158

Table 1.—Continued

TREATMENT	NO. OF PARENT PLANTS	AVERAGE NO. OF RUNNERS PER PARENT PLANT PRODUCED TO						
		6-12-40	6-22-40	7-2-40	7-12-40	7-22-40	8-1-40	8-11-40
Check	108		0.430	1.392	2.495	2.794	2.841	2.906
Lead arsenate-sand, 1–20	102		0.323	1.186	2.000	2.421	2.509	2.568
Starter Solution	98	0.112	1.206	2.247	3.082	3.319	3.422	3.474
Magnesium arsente-sand, 1–50	99		0.222	0.787	1.757	2.040	2.111	2.192
Lead arsenate-sand, 1–20 plus Starter Solution	100		0.820	1.868	3.020	3.272	3.343	3.404
Average of 3 checks		.003	.620	1.566	2.696	2.980	3.030	3.073
Least difference at odds of 99:1		—	—	—	±.931	—	—	—

Runners appeared on Dorsett plants of all treatments by June 22. Among the lead arsenate-sand treatments it was found, throughout the season in general, that the average number of runners produced per parent plant was smaller for those plants treated with the greater concentrations of the sand-arsenical mixtures (Fig. 4). During the early part of the season the same was true for the Dorsett plants treated with the three concentrations of magnesium arsenate-sand. Untreated Dorsett plants produced a maximum of runners during the 10-day period July 12–22. In comparing runner production of treated and untreated plants it was found that significantly fewer runners per parent plant were produced by July 22 on plants treated with magnesium arsenate-sand 1–10, 1–20, and 1–50 and lead arsenate-sand 1–10, while on August 11 the same was true of plants treated with magnesium arsenate-sand 1–10, and 1–20, and lead arsenate-sand 1–10.

Runners appeared on Mastodon plants of one check treatment and the plants of the starter solution treatment by June 12, while plants of the remaining treatments produced runners by June 22. Since blossoms were allowed to mature and produce fruit, it is impossible to state when the peak of runner production for the variety Mastodon would have been reached. By July 12, only those plants treated with magnesium arsenate-sand 1–50 had produced significantly fewer runners per parent plant than did the average of the three check treatments (fig. 2).

Runner production of plants of all four varieties was equally reduced by the corresponding concentrations of lead arsenate-sand 1–10 and magnesium arsenate-sand 1–10, while runner production of Catskill and Mastodon plants treated with lead arsenate-sand 1–20 and magnesium arsenate-sand 1–20 were likewise equally reduced. Premier and Dorsett plants treated with magnesium arsenate-sand 1–20 produced fewer runners per parent plant than did those plants treated

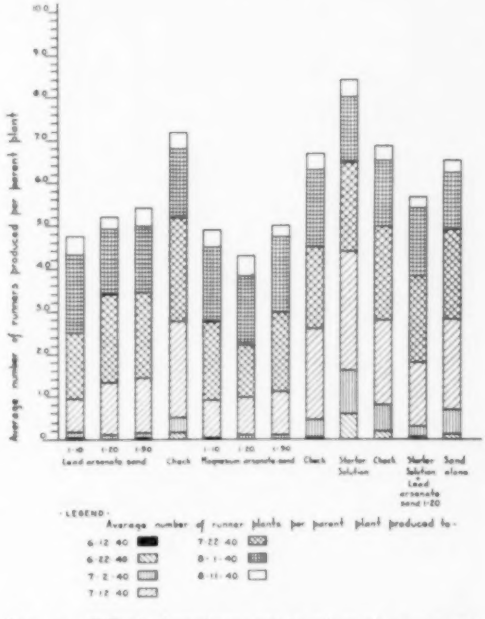


FIG. 4.—Effect of various root treatments on runner production of the strawberry variety Dorset.

with lead arsenate-sand 1–20. Plants of all varieties, except Premier, treated with lead arsenate-sand 1–50 produced more runners per parent plant than did those plants treated with magnesium arsenate-sand 1–50.

It was found in general that, in a given variety, plants tended to produce a maximum number of runners during a definite

period in the growing season regardless of treatment. However, Catskill, Dorsett and Mastodon plants treated with starter solution, Mastodon plants treated with lead arsenate-sand 1–20, and Catskill plants treated with sand alone, produced their maximum numbers of runners before the time of maximum runner production of the three check treatments was reached. Also, Premier plants treated with lead arsenate-sand 1–50, and magnesium arsenate-sand 1–10, and 1–20, and Dorsett plants treated with lead arsenate-sand 1–10, and magnesium arsenate-sand 1–20 produced their maximum number of runners after the period during which runner production of the three check treatments was reached. In addition, it was found in general that plants of all varieties treated with sand-arsenical mixtures had a higher rate of runner production after the period of maximum runner production than did the average of the check treatments.

Plants of all four varieties treated with lead arsenate-sand 1–20 plus starter solution produced a greater average number of runners per parent plant than did plants treated with lead arsenate-sand 1–20.

Previous investigations (Kerr, 1940) have shown that lead arsenate-sand 1–20 is the most effective sand-arsenical mixture in controlling white grubs in strawberries. In addition, the results obtained during the course of this investigation indicate that runner production of plants treated with the mixture is not significantly different from that observed with untreated plants.

Precipitation on the site of the experimental planting was 4.68, .98, 4.74, and 3.73 inches during the months of June, July, August, and September, respectively, while at the field laboratory located 3.4 miles east of the experimental planting the precipitation during the months of May to September inclusive was 4.11, 4.55, .96, 4.86, and 3.84 inches.

SUMMARY.—In an investigation of various sand-arsenical mixtures, used to control white grubs, *Phyllophaga* spp. and to determine their effect upon the growth of strawberries, it was found that lead arsenate and magnesium arsenate-sand mixtures retarded growth of the strawberry varieties Catskill, Premier, Dorsett, and Mastodon during the early part of the season. Among plants of all four varieties treated with lead arsenate-sand mixtures it was found in general, that the more concentrated the sand-arsenical mixture, the greater the reduction in growth during the early part of the season. Premier and Dorsett plants treated with magnesium arsenate-sand mixtures reacted, in growth activities during the early part of the season, the same as plants of all varieties to lead arsenate-sand mixtures, while Catskill and Mastodon plants were retarded less by the mixture of magnesium arsenate-sand 1–20.

Runner production of plants of all four varieties was equally reduced by the corresponding concentrations of lead arsenate-sand 1–10 and magnesium arsenate-sand 1–10, while runner production of Catskill and Mastodon plants treated with lead arsenate-sand 1–20 and magnesium arsenate-sand 1–20 were likewise equally reduced. Premier and Dorsett plants treated with magnesium arsenate-sand 1–20 produced fewer runners per parent plant than did those plants treated with lead arsenate-sand 1–20. Plants of all varieties, except Premier, treated with lead arsenate-sand 1–50 produced more runners per parent plant than did those plants treated with magnesium arsenate-sand 1–50.

Catskill plants treated with magnesium arsenate-sand 1–10 and 1–50 and lead arsenate-sand 1–10 produced by August 1, and August 11, significantly fewer runners per parent plant than did the plants of the three check treatments. Premier plants treated with starter solution had produced by July 12 and August 11, significantly more runners per parent plant than did the plants of the three check treatments, while there were no significant differences in the average number of runners produced per parent plant between plants treated with arsenicals and untreated plants. In the variety Dorsett it was found that significantly fewer runners were produced by July 22 on plants treated with magnesium arsenate-sand 1–10, 1–20, and 1–50, and lead arsenate-sand 1–10, while on August 11 the same was true of plants treated with magnesium arsenate-sand 1–10 and 1–20 and lead arsenate-sand 1–10. By July 12, only those Mastodon plants treated with magnesium arsenate-sand 1–50 had produced significantly fewer runners per parent plant than did those plants of the three check receiving no treatment.

The addition of starter solution to the

lead arsenate-sand 1–20 treatment benefited runner production in the four varieties investigated.

Lead arsenate-sand 1–20 has been shown to be the most effective sand-arsenical mixture in controlling white grubs in strawberries. In addition, the results obtained during the course of this investigation indicate that runner production of plants treated with the mixture is not significantly different from untreated plants. —2-13-41.

LITERATURE CITED

Kerr, T. W., Jr. 1939. Lead Arsenate as a Possible Control for White Grubs in Strawberries. JOUR. ECON. ENT. **32**(1): 153.

Kerr, T. W., Jr. 1940. Arsenicals for Controlling White Grubs in Strawberries. JOUR. ECON. ENT. **33**(4): 693–8.

Sayre, C. B. 1939. One and a Half Tons of Tomatoes from Fertilizer Costing 48 Cents. New York (Geneva) Agr. Expt. Sta. Quarterly Bul. **5**(2): 1, 5.

Taylor, A. E., F. B. Howe, C. S. Pearson, W. J. Moran. 1929. Soil Survey of Erie County, New York. U.S.D.A. Bureau of Chemistry and Soils, Series 1929, **14**: 33.

A Method and Contrivance for Sampling Pea Aphid Populations[1]

K. W. GRAY and JOE SCHUH, *Oregon Agricultural Experiment Station Corvallis*

A method of sampling pea aphid, *Macrosiphum pisi* Kaltenbach, populations by which two or more people could sample the same area and obtain the same answer take the sample quickly, and do the sampling without previous experience, was sought from the beginning of the studies on control of this pest in Oregon. It was necessary that such a method be found to make possible the use of a large number of field plots for testing various materials. The application of the materials presented no problem because two people with a power machine applied dust to 40 plots replicated eight times in about eight hours. Thus 320 individual plots were treated the same day. It was advantageous to be able to sample all the plots the same day, not only to obtain directly comparable results, but because of the urgency of other experimental projects. The sampling method had to be such that no previous experience with aphid sampling was necessary, for it was impossible to hire a large crew of people experienced in sampling aphid populations. The field trials were separated by as much as 300 miles. This made it impracticable to train and use the same crew on all fields. In addition, it was deemed advisable to have the sampling done by people who had no knowledge of the treatment given any plot. The method of sampling as described here met the requirements of this project better than any other method tried, but it is not assumed to be perfect. It is hoped that the discussion of the method may add impetus to the development of one which all investigators may adopt for measuring pea aphid populations.

The method used in the experimental control program evolved from: (1) the method of counting the aphids on the plants without disturbing the aphids or plants, (2) to the method of separating the plant tips and aphids by shaking the insects from each tip into an insect net and later counting them, (3) finally, to the method of separating the aphids and plants by exposing both to fumes of methyl-iso-butyl ketone in a sampling can and later counting the aphids. The first sampling in connection with the experimental control program was done on trellis peas. It was impossible to make sweep net counts; so the aphids were counted on the plants. This was a slow and laborious method, but produced fairly consistent results when carefully done.

The first pea aphid population records made on broadcast peas were taken by net sweeps. This method was satisfactory as long as the same person took all the samples on all of the plots, but necessarily limited the scope of the experimental control program because of the time involved. A method which consisted of plucking the top six inches of 25 plants taken at random through the plot and shaking the aphids from each tip into an insect net,

[1] Submitted for publication as Technical Paper No. 373 of the Oregon Agricultural Experiment Station.

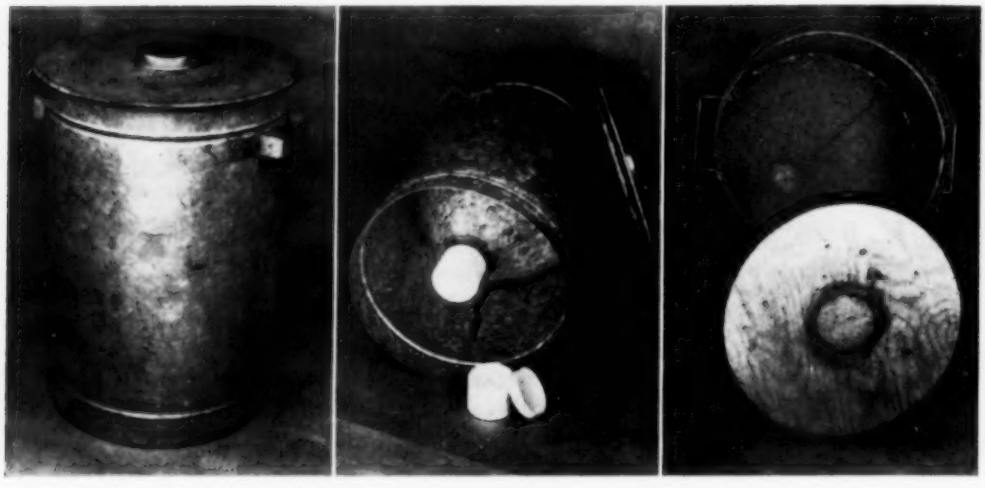


FIG. 1.—Views of the sampling can used in pea aphid counts.

transferring the aphids to a 4-ounce *Sealrite* carton, and later counting them in the laboratory was adopted. This method reduced the variation between samples taken on the same plot by two individuals and permitted the employment of people who had no previous experience in sampling aphid populations. It also reduced the time required to take the samples. One person could take 40 samples in about eight hours, which made it possible for a crew of eight to sample in one day a field plot set-up consisting of eight blocks, each containing 40 plots. About four hours is required for one person to count the aphids taken in the 40 samples.

Shaking the aphids from the tips and then counting was an improvement over the counting of aphids on the plants or the sweep net method, but was beset with the following difficulties: (1) Beating each tip to dislodge the aphids was very tiring. It is doubtful that as high a percentage of the aphids were removed from the last tips picked as from the first. (2) It is practically impossible to shake the first instar aphids from the plants. (3) Many aphids were lost in the shaking process and while being transferred from the insect net to the cartons. These losses were aggravated by gusts of wind. For that reason, they were not constant and thus introduced an error. (4) There was always considerable debris, such as pieces of leaves, pods, blossoms, and stems in the samples. The heavier pieces often mashed aphids, and all the debris interfered with the counting. (5) No two persons handled the plant tips exactly the same way during the process of plucking and transferring to the net. A variable number of aphids were lost in this process.

The first four of these objections to the sampling method were eliminated by use of a sampling can (Figs. 1 and 2). This device consisted of a can containing a large funnel covered with hardware cloth at the top. Above the hardware cloth was a chamber six inches tall by twelve inches in diameter closed at the top by a tight-fitting cover in which a pad was fastened. This pad was saturated with methyl-iso-butyl ketone. The bottom of the funnel exactly fitted the inside of the 4-ounce containers.

In sampling, the plant tips were picked into an insect net and then dumped into the sampling can. The lid was replaced and the aphids exposed to the fumes of the methyl-iso-butyl ketone for five minutes. The sampling can was then given 50 vigorous shakes. The aphids dropped through the screen and were caught in the container, which was then removed and its lid put on. The plant tips were dumped out, another carton placed over the bottom of the funnel, and the next sample of tips dropped into the sampling can. While one sample was being exposed to the fumes in the can, the next plot was sampled. In this way, no time was lost waiting for the five-minute exposure of the aphids in the sampling can. As aforementioned, the sampling can eliminated the first four objections to the method of shaking the aphids loose by hand. In addition, the time required to sample 40 plots was re-

duced from about 8 to about 4 hours.

This method of sampling the plots and later counting the aphids in the laboratory made it possible for growers, canners, and seed dealers to take an active part in the experimental control program. Many such people volunteered to help with the work. This active participation in the studies gave them a basis for evaluating the results and an appreciation of the detailed work necessary to obtain accurate data.

In detail, the plot sampling was done as follows:

1. The *Sealrite* containers were placed by the plot markers and the plot numbers recorded on them.
2. Each person was assigned a block to sample. He was instructed to:
   (a) Pluck tips so as not to lose those aphids disturbed by plucking.
   (b) Pluck tips of uniform length (the top six inches of the plant).
   (c) Obtain the sample from the full length of the plot.
   (d) Disturb none of the nearby plants as he picked a tip.
   (e) Pay no attention to the number of aphids on the tips to be plucked.
   (f) Take short, medium, and tall plants in equal proportions.
   (g) Take exactly 25 tips from each plot.
   (h) Check the number on the container with that of the plot marker.
   (i) Dump the aphids and tips into the sampling can, leave them five minutes, give the can exactly 50 shakes vigorously enough to bounce the tips against the top of the can with each shake, remove the container from the funnel, replacing it with the one for the next plot, and dump out the old tips. No one unfamiliar with the method was permitted to begin sampling until he could be watched by the instructor as he sampled his first plot.
3. After the samples were in the cartons, the numbers were again checked and the cartons packed in cracked ice a few minutes after being taken to prevent predators destroying the sample of aphids.
4. The samples were taken to a laboratory and the aphids counted, either by the pickers or by another crew. In either case, one person counted entire blocks. One-half cubic centimeter of ether was shot into each container by a hypodermic needle before they were opened. The aphids were spread out on white paper and counted.
5. The counts were recorded on the cartons and then transcribed to a chart.

The reaction to five chemicals by the pea aphid on pea tips was studied in selecting methyl-iso-butyl ketone for use in the sampling can. These five chemicals were: strong ammonia water, dichloroethyl ether, ethyl ether, methyl-iso-butyl ketone, and 40 per cent nicotine sulphate. The method of testing consisted of observing the actions of the aphids on pea tips in petri dishes containing fumes of these chemicals. Small pieces of cotton were soaked with the chemicals and placed inside the dishes and left for five minutes. One pea tip having from 30 to 50 aphids of various ages was then laid in each dish and the cover replaced and the reactions

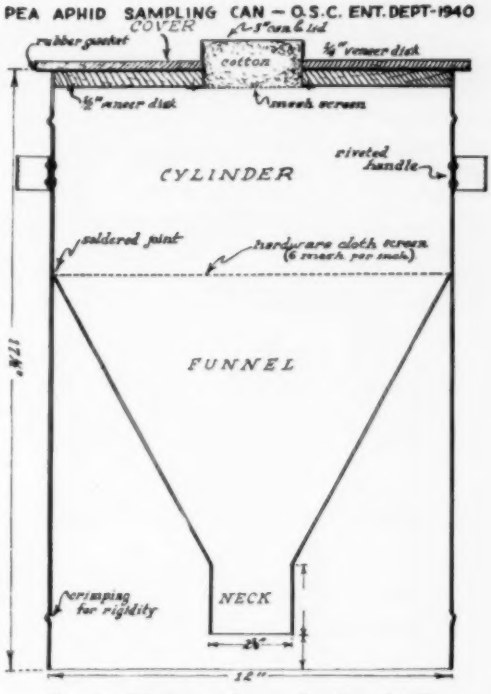


FIG. 2.—Diagram of can showing details of construction.

of the aphids observed. Special attention was paid to the first instar aphids. The room temperature was 70° F.

The ammonium hydroxide caused those aphids next to the cotton pad to begin moving, but the others were not disturbed during the first five minutes of the exposure.

Dichloroethyl ether immediately produced a decided reaction but soon anaesthetized the insects. Most of the first instar aphids did not release their hold.

Ethyl ether produced the same effect but in a shorter time as did dichloroethyl ether.

Methyl-iso-butyl ketone caused all the aphids to drop from the plant tip. Even the first instar aphids, withdrew their

stylets and dropped from the plants in less than five minutes. All were anaesthetized in about ten minutes but recovered when taken out.

The 40 per cent nicotine sulfate produced no noticeable effect in two hours.

No further trials were conducted with these or other chemicals because methyl-iso-butyl ketone produced the desired results and because of the rush of field work. Eight sampling cans were constructed and put into operation.

The first test made on the sampling can was to determine the most efficient time of exposure of the aphids and plant tips in the gas chamber of the can and the amount of shaking necessary to separate the aphids and the plants parts. This was done by placing samples of 50 tips in the can and giving it 50 shakes at five-minute intervals for 15 minutes then examining the tips for remaining aphids. Six such samples were used. The data are presented in table 1.

sible to remove the sample from the can by the time the next sample was picked.

A test was made to determine whether or not two or more people could take samples from one area and obtain an equivalent figure. The areas selected for sampling were all located in a field, part of which had been left undusted. It was decided that the size of the areas sampled should conform to the size of the experimental test plots being used to test the effectiveness of various dust formulae, that is 8 feet by 40 feet. To insure that the area sampled equalled that of a test plot, a string tied to two stakes 40 feet apart was stretched over the peas to mark the exact area to be sampled. Twenty-five knots were tied in the string at 18-inch intervals. Each person sampling, plucked the tip nearest directly under each knot and always travelled on the left of the string. When one person had taken his sample, the string was moved to the right about two feet to eliminate error introduced by dis-

Table 1.—A comparison of the number and portions of pea aphids removed from 50 plant tips by 50 shakes of the sampling can at five-minute intervals.

Sample No.	1		2		3		4		5		6		Total	
Minutes of exposure in gas chamber	Aphids Taken Out													
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
5	5421	85.6	5237	89.5	3257	89.7	2819	90.7	3684	90.8	3387	92.0	23,805	89.3
10	607	9.6	440	7.5	241	6.6	211	6.8	327	8.0	230	6.2	2,056	7.7
15	208	3.3	124	2.1	84	2.3	58	1.9	40	1.0	53	1.4	567	2.1
Remainder	93	1.5	52	.9	51	1.4	20	.6	8	.2	14	.4	238	.9
Total	6329		5853		3633		3108		4059		3684		26,666	

It was found that 85.6 to 92 per cent of the aphids were removed by 50 shakes after an exposure of five minutes. The average was 89.3 per cent. Another 50 shakes at the 10 minute interval netted from 6.2 to 9.6 per cent for an average of 7.7 per cent. Fifty shakes at the 15-minute interval netted from 1.0 to 3.3 per cent with an average of 2.1 per cent of the aphids. A careful examination of the tips after 15 minutes exposure and 150 shakes showed that from 1.5 to 0.2 per cent of the aphids remained on the plant parts. The average was 0.9 per cent. Five minutes exposure to the fumes of the chemical followed by 50 shakes in the can was adopted in making the samples because approximately 90 per cent of the aphids were removed consistently in that time and because about 5 minutes is required to pick 25 tips from the experimental plots. This made it possible

turbance of the vines as the previous sample was taken. The areas sampled were: (1) entirely in the undusted part of the field, (2) one-half in the dusted and the other in the undusted part, (3) entirely in a dusted area, and (4) in a dusted portion of the field but on a corner where the duster turned. The results are given in table 2.

The analysis of variance indicated that the difference between means necessary for significance with odds of 19 to 1 was 444. Since the greatest difference found is 304, it may be stated that the samplers arrived at equivalent quantities.

The sampling cans were used in measuring aphid populations in fields as well as in the experimental plots. When a sample was taken on a field, 50 or 100 tips were taken. The tips were selected by taking the tip of the plant nearest to a point eight-

Table 2.—A comparison of the pea aphid population records obtained with a sampling can by four individuals all sampling the same areas in a pea field.

INDIVIDUAL SAMPLING	AREA 1	AREA 2	AREA 3	AREA 4	TOTAL	MEAN,[1] 25 TIPS
Stephenson	3,684	2,812	154	304	6,954	1,738
Usher	3,108	2,159	133	337	5,737	1,434
Mote	4,059	2,545	55	212	6,871	1,718
Gray	3,633	2,027	133	281	6,074	1,518
Total	14,484	9,543	475	1,134	25,636	

[1] Difference between means necessary for significance with odds of 19 to 1=444.

een inches ahead of the right foot ever so often. The number of steps taken between pickings was dependent on the size of the area to be sampled. Where it was desired to take samples on successive dates, definite markers were noted so that the later samples could be taken in the same area. An example of a field population record is given in figure 1. Four people participated in obtaining this record because the work was carried on in conjunction with another experiment station project. It was impossible for the same person to make all the counts. The record as shown in the graph indicates that two or more people can sample the same area and obtain equivalent population figures.

SUMMARY.—A method of sampling pea aphid populations by means of which two or more persons could sample the same area and obtain equivalent results was developed. It consisted of plucking the top six inches of the plants at random in an area, shaking the aphids from the plant tips, and counting the aphids. A sampling can which consisted of a funnel covered with coarse screen mounted below a gas chamber was used to separate the aphids from plant parts. The plant tips and aphids were placed in the gas chamber containing fumes of methyl-iso-butyl ketone and left for 5 minutes. The fumes of the chemical caused the aphids to drop from the plant parts. The can containing the plant tips and aphids was given 50 shakes thus causing the aphids to fall through the screen and be caught in a 4-ounce *Sealrite* carton at the bottom of the funnel. The aphids were counted in the laboratory later. One person, without previous experience, could take 40 samples by this method and count the aphids in about 8 hours.—2-17-41.

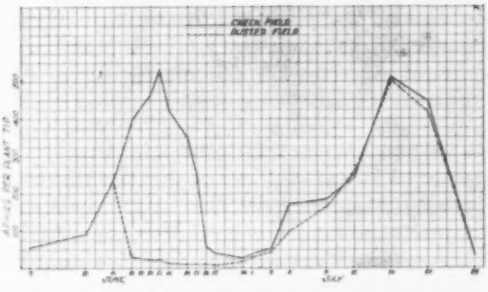


FIG. 3.—A typical field population record obtained by different individuals using the sampling can.

MEGAMELUS DAVISI INFESTING WATER LILY IN HAWAII

The leafhopper, *Megamelus davisi* Van Duzee,[1] was first observed near Pearl City, Oahu by the writer on February 25, 1941. All adult leafhoppers examined were of the short-winged form. Since then, two long-winged specimens have been taken at three week intervals during April. Presumably the leafhopper was introduced with plants from aquatic gardens on the mainland.

The damage to old established plants, *Nymphaea* sp., is not apparent. But newly planted suckers up to six months old have been considerably set back, producing poor growth of leaves and inferior flowers. In view of the leafhopper's restricted choice of host plant and the small acreage involved, it is hoped that clean culture will eradicate this pest.—4-26-41.

S. H. AU
Board of Agriculture and Forestry
Honolulu, T. H.

[1] Family Delphacidae. Determination by Mr. O. H. Swezey.

Cooperative Japanese Beetle Work in Maryland

GEO. S. LANGFORD, F. B. WHITTINGTON, R. H. VINCENT and E. N. CORY,
University of Maryland, College Park, Maryland

The University of Maryland, the Bureau of Entomology and Plant Quarantine, and local county governmental agencies are cooperating in Maryland in a state-wide endeavor to retard and control the Japanese beetle. The program is now beginning its fourth year. Every effort has been made to keep the work on a scientifically practical basis, and in order to keep the program balanced, all control practices, with merit, have been used or advocated. Farm leaders and others have been consulted from time to time for their advice on the practical application of the work. These conferences have been supplemented with questionnaires in an attempt to obtain the general reaction of the public in regard to the work. Each year over 90 per cent of the people contacted expressed approval and requested that the work be continued. This year questionnaires were returned by 6,116 individuals. The replies showed that 94.6 per cent of those replying favored the program and wanted it continued. The program is designed to delay increase and spread in lightly infested areas and to cooperate with farmers and others in controlling the beetles in heavily infested areas.

There is no all-inclusive control method available for fighting the Japanese beetle. Therefore the full force of control can only be obtained by coordinating all control methods in such a manner as to permit all people with a beetle problem to engage actively in control work. Eliminating the potentialities of biological control there is not available one economically practical control measure that is fully effective for preventing beetle damage to staple crops. Nor is there one that will fully meet the general needs of the public.

The cost of the more effective control measures as spraying, dusting, and soil treatment commonly advocated in the literature is such as to exclude their use except for a few comparatively prosperous home owners and a very small group of farmers growing fruits or specialized crops. Dependence on these methods would leave well over 99 per cent of the Maryland farmers without a practical control practice. Crop substitutes; delay in planting corn; plowing, discing, and harrowing to pulverize soil and kill grubs, and trapping are the only economically practical control measures available to the average general farmer. Any method used or recommended has its limitations and drawbacks. In Maryland every endeavor is being made to coordinate all control practices. The better practices are being advocated and reinforced with those having lesser merit. It is believed that such a policy tends to create a broad stabilizing force which functions to bring an unbalanced situation into equilibrium.

The work in Maryland is based on an energetic state-wide program in which biological control, looking toward permanent relief, is stressed and supplemented with demonstrations and education on trapping, spraying, lawn treatments, planting plans and cultural practices. In lightly infested areas traps have been operated for retardation purposes. This year the milky disease spore dust was applied in the vicinity of all traps in the lightly infested areas that caught beetles.

A thorough analysis and survey of the Maryland situation strongly indicates that definite progress has been made in retarding and delaying the spread of the beetle in lightly infested areas. Surveys in the heavily infested areas indicate that the program is now having considerable influence on the beetle population.

This paper is presented as a review of the work done.

BIOLOGICAL CONTROL.—The most ideal way of obtaining permanent relief from the Japanese beetle would be to establish a biological complex that would reduce the beetle population to a point below which it would cause commercial damage. The recent work by the Bureau of Entomology and Plant Quarantine, with both parasites and the milky disease, affords encouragement. It should be stated, however, that biological control is slow. People are eager to have this work done, but tire of waiting for results and usually demand that some form of control in which definite results can be immediately visualized.

Biological control in Maryland is a major endeavor and is being stressed. To date practically all biological control work has been confined to work with the milky disease and two species of parasites; *Tiphia vernalis* Rohwer and *T. popilliavora* Rohwer.

MILKY DISEASE.—A method of manufacturing and distributing this disease was recently announced by the Bureau of Entomology and Plant Quarantine. Tests in Maryland indicate that from 50 to 80 per cent of the grubs in properly treated land will be killed in one year. This disease is now being widely disseminated throughout the state. During the past year over 10,000 pounds of spore dust were produced and over 8,843 properties, involving 4,533 acres were treated. Every effort has been made to distribute the disease evenly in heavily infested areas. Even distribution has been accomplished through the use of Geological Survey maps blocked off into square-mile areas. In the most heavily infested areas three 1-acre plots have been treated in each square mile. Over 1,300 square miles have been treated in this manner. This control shows so much promise that it is planned to increase the production and distribution of the disease.

PARASITES.—Parasites offer another possibility of permanently reducing beetle populations. The two species of *Tiphia* wasps, *T. vernalis* and *T. popilliavora* have been used in Maryland. During the past three years a total of 414 colonies have been released. At present an attempt is being made to rear *T. vernalis* by mass production methods. Last spring over 75,000 eggs were obtained.

TRAPPING.—Traps have been rather generally used in Maryland. They are not effective for eliminating beetles, nor will small numbers eliminate damage to favored food plants. They do catch large numbers of beetles and experiments indicate that if properly operated and used at the rate of 1 to each acre of land from 30 to 50 per cent of the total number of beetles produced on a farm may easily be caught. They also satisfy a desire for action by people not equipped to use other methods of control. Extensive surveys in which questionnaires were used to determine public opinion, and in which from 6,000 to 15,000 replies were obtained each year show that more than 90 per cent of the individuals using traps are convinced that they are helpful. All evidence indicates that if they are used in large numbers they will relieve the pressure of beetle feeding on certain general farm crops. This may be illustrated by pointing out results obtained in Harford County. There are approximately 198,000 acres of crop land in the county. Approximately half of this area is heavily infested with beetles. There were used in the county 18,455 traps, and 336,247 quarts, or 109.8 tons of beetles were caught. Farm surveys indicate that staple crops such as corn, alfalfa and soybeans are seldom seriously injured if the average grub population in a community is one beetle or less per square foot. The estimated average grub population in the heavily infested area of Harford County was approximately 3 grubs per square foot. On this basis the traps operated in that county removed enough beetles to protect the quantity of staple crops that is ordinarily grown on 10,000 acres of crop land.

This past year there were operated in Maryland 127,122 traps. These traps caught 4,591 barrels or 275 tons of beetles. Traps, without doubt, have an influence on the general beetle population when used in connection with other control methods as spraying and cultural practices.

SPRAYS AND DUSTS.—Sprays and dusts are effective for repelling beetles and protecting many plants. Two to three applications of a good spray are usually necessary for effective protection. The principal objection to sprays and dusts is the cost. The average farmer or individual is not financially able to provide the expensive equipment needed. Even where the spray equipment is available the cost of spraying is frequently excessive when compared with the value of the commodity. Another objection to spraying is that it does not kill beetles, but only drives them to other plants not sprayed.

Sprays are being used and recommended wherever practicable. Tests and demonstrations are being made to determine the efficiency of various spray mixtures for protecting plants. This past year 18 spray mixtures were tested. Arsenate of lead with an appropriate sticker was the best of the spray materials used. Derris or rotenone dust, with a good sticker, was the most efficient of the non-poisonous

materials tested. Heavy applications of hydrated lime, as dust, aids in protecting corn and other plants.

LAWN TREATMENTS.—Education on the use of arsenate of lead for grub control in lawns is being stressed. During the past three years 58 actual field demonstrations showing the method of application were made. Large areas of grass land have been privately treated. This treatment is only being recommended in cities and towns and on home lawns. It is felt that if a majority of the residents in cities and towns would treat their lawns their Japanese beetle injury would be ameliorated. The main objection to the treatment, as far as the public is concerned, is that it does not prevent the influx and feeding of beetles on favored food plants.

PLANTING PLANS AND CULTURAL PRACTICES.—In educating the public on the use of plant materials not attacked by the beetle, 11,888 bulletins and mimeographed sheets containing lists of desirable plants have been distributed throughout the State. County agents and home demonstration agents have stressed this phase of the work in county papers and to garden clubs. Specialists from the University in three years have discussed planting plans in 228 talks. This information is being accepted and used by many home owners in planting and ornamenting the gardens in and around their homes.

Information on farm crops not fed upon by the beetle is being disseminated through the offices of all county agents in counties having heavy beetle infestations. This is being supplemented by demonstrations on planting dates for corn to eliminate damage. If corn can be planted so that it will silk after most of the beetles have disappeared, beetle damage will be negligible.

A three-year study in cooperation with the agronomy department, of planting dates indicate that the marginal period for planting to avoid both beetle and frost injury is narrow. On the basis of the work done it appears that there is no certain planting date which will guarantee freedom from both types of injury. In exceptional years injury will occur. The best that can be done is to use dates that, on an average, are favorable. The following planting dates are being suggested to growers in northeastern Maryland:

Long season corn	May 25 to June 1
Medium season corn	June 1 to June 7
Short season corn	June 7 to June 14

The practice of delaying corn planting has become rather general in heavily infested areas. The County Agent in Cecil County states that over 50 per cent of the farmers in that county are attempting to delay corn planting to avoid beetle damage. This practice in Maryland, while it had the advantage of eliminating much beetle damage, quite often upsets the entire farm program.—1-17-41.

Value of the Petal-Fall Application of Lead Arsenate in Controlling the Plum Curculio on Peach in the South

OLIVER I. SNAPP, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In the South adults of the plum curculio *Conotrachelus nenuphar* Hbst., usually begin to appear from hibernation when peach trees bloom and are disseminated throughout the orchards by the time of petal fall or before (Snapp 1940). The calyx of the flower is a favored food for the plum curculio at this time, and there is considerable feeding on this and other parts of the flower and young leaves upon the appearance of the insect from hibernation. Therefore, an application of lead arsenate at petal fall is included in the regular peach spray schedule for the South to kill plum curculio adults before oviposition begins. Although previous experiments have shown the value of this application, additional data on the value of spraying peaches in the South at petal fall were obtained in experiments conducted in a commercial orchard near Fort Valley, Ga., in 1940.

In 1940 plum curculio adults began to appear from hibernation on March 20, before full bloom of the first-blooming varieties of peach trees, and they were appearing in numbers on March 29, when about 25 per cent of the petals had fallen. By

April 1 three-fourths of the petals had fallen and on April 2 the petal-fall application of lead arsenate was made.

Five schedules of treatments were each replicated five times in a latin-square arrangement of 25 plots, each containing 36 trees (6 by 6 tree rows). This paper deals with three schedules. The trees receiving one of these schedules included the petal-fall application of lead arsenate and the other two did not.

The trees were jarred three times between the petal-fall and shuck-off sprays (the first two sprays in the full schedule) and five times after the chuck-off spray to remove overwintered adults.

The results of jarring during the period between petal fall and shuck off are given in table 1.

Table 1.—Effectiveness of petal-fall application of lead arsenate in reducing overwintered populations of plum curculio adults, Fort Valley, Ga., 1940.

Spray Schedule	Number of Trees	Number of Curculios Removed by Jarring			
		Apr. 5	Apr. 9	Apr. 10	Total
Petal-fall application included	175	107	42	35	184
Petal-fall application omitted	174	321	90	83	494
	178	305	104	100	509

The results of this experiment show that there were almost three times as many plum curculio adults on the trees that did not receive the petal-fall application of lead arsenate as on those that received this spray. These results confirm data previously obtained in support of the petal-fall application in the spray schedule for plum curculio control on peaches in the South.

Plum curculio adults are found in greater numbers on peach trees nearest places of hibernation. The number of curculios removed from various parts of the orchard in eight jarrings between petal-fall and the stone-hardening stage of the fruit are show in table 2. With each treatment replicate 1 was on one end of the orchard, near a county road, and replicate 5 was on the opposite end, near a wooded area.

Table 2.—Populations of plum curculios on peach trees nearest places of hibernation. Replicates 1 and 5 were on opposite edges of the orchard, No. 1 near a county road and No. 5 near a wooded area. Fort Valley, Ga., 1940.

Replicate No.	Number of Curculios Removed by Jarring			
	Trees Receiving Petal-Fall and Shuck-Off Sprays	Trees not Receiving Petal-Fall and Shuck-Off Sprays		
		Schedule 1	Schedule 2	Total
1	57	151	142	350
2	78	93	127	298
3	66	103	97	266
4	56	152	204	412
5	115	242	217	574
Total	372	741	787	1,900

The regular jarring of outside rows of peach trees or those nearest to places of hibernation early in the spring would prevent the dissemination of many curculios throughout the orchard.—1-7-41.

LITERATURE CITED

Snapp, Oliver I. 1940. Further studies of the plum curculio in the Georgia peach belt. JOUR. ECON. ENT. **33**(3): 453–6.

THE MOSQUITOES OF ARKANSAS

The Arkansas State Board of Health has recently issued a revision of a bulletin with the above title, first published in 1939, written by Stanley J. Carpenter, Entomologist of the Board of Health. The bulletin contains 87 pages and should be most useful to entomologists, especially to those directly interested in mosquito problems and to teachers of entomology.

In addition to a general discussion of the mosquito problem and the problems of mosquito control, both of which are presented in a very adequate manner, the bulletin includes much other useful material not always found in such publications.

A discussion of structures of the insects sufficient to make the excellent keys and specific descriptions usable is an excellent feature of the bulletin. The keys and descriptions are likewise carefully prepared and arranged.

Suggestions for collecting all stages with descriptions of special apparatus for the purpose are included. Some directions for preserving and mounting are given, especially for the larvae. Methods of rearing and directions for maintining live cultures add to the value of the work.

The illustrations include figures of some of the collecting and breeding apparatus and of diagnostic characters of several important species of mosquitoes.

Studies of Codling Moth Cocooning Habits

A. M. Woodside, *Field Laboratory, Virginia Agricultural Experiment Station, Staunton*

During the past four years the writer has conducted at Staunton, Virginia, some studies of chemically treated tree bands as a supplementary means of control for the codling moth, and in the course of these experiments considerable data have been accumulated on the behavior of codling moth larvae in seeking cocooning quarters.

Percentage of Larvae Trapped by Bands.—Van Leeuwen (1929) found that 20 per cent of the larvae that left the fruit cocooned in bands around the trunks of the trees, and Cutright (1937) found an average of 28 per cent of the larvae cocooned in the bands. Newcomer *et al.* (1933) reported that 33 to 68 per cent of the larvae that cocooned did so in the bands. Worthley (1932, 1934) reported that 70 to 96 per cent of the larvae found were in the bands, and Farrar & Flint (1933) reported similar results.

In 1938 and 1939 after the removal of treated bands apple trees were examined to determine how many larvae had cocooned on them. Each tree was examined from a point slightly below the ground line to the tips of the branches. All of the loose bark was removed and examined and all decayed places and cavities were probed, wood being removed with a chisel when this was necessary to reach the bottom of a deep cavity. In 1938 six Winesap and five Stayman Winesap trees were examined. The crotches of some of these trees had been split open at one time, and decay had resulted. All had stubs of broken branches, providing ideal places for codling moth larvae to cocoon. Although these trees had been scraped in the spring of 1937, there was considerable loose bark on the trunks and larger branches. There was a sparse growth of grass under the trees. Eight of the trees had been banded with beta-naphthol-treated strawboard, and three with untreated strawboard. About 70 per cent of the larvae had cocooned in the bands, and there was very little difference in the catch in treated and untreated bands (Table 1). In 1939 eight Winesap and eight Stayman trees were examined. Eight had been scraped very thoroughly in the fall of 1938, but the other eight had not been scraped for three or four years. The scraped trees and four of the unscraped trees were banded with beta-naphthol-treated strawboard, and the other four with untreated strawboard. The slightness of the difference in catch on scraped and unscraped trees is surprising (Table 1).

Table 1.—Percentage of codling moth larvae that cocooned in or under bands on apple trees, Staunton, Virginia, 1938 and 1939.

Year and Type of Band	Treatment of Trees Before Banding	Larvae and Empty Cocoons	
		Total Number on Trees and in Bands	Percentage in or Under Bands
1938			
Treated	Scraped	1,152	71.3
Untreated	Unscraped	842	69.1
1939			
Treated	Scraped	700	68.9
Treated	Unscraped	386	63.0
Untreated	Unscraped	393	57.0

Relative Attractiveness of Treated and Untreated Bands.—Steiner (1929) suggested that the beta-naphthol had a repellent effect on codling moth larvae, but Worthley & Marston (1936) found that treated half-bands caught twice as many larvae as untreated half-bands on the same trees. In 1938 an experiment was started to test the relative attractiveness of beta-naphthol-treated strawboard and untreated strawboard as cocooning places. Half-bands of each kind were placed on opposite sides of the trunks of 24 apple trees. The treated half was placed on the north side of the first tree, the east side of the second, the south side of the third, and the west side of the fourth; this order being repeated throughout. The experiment was repeated in 1939. In 1938, 74 per cent of the larvae were in the treated halves, and in 1939, 60 per cent were in the treated halves (Table 2). In 1939 half-bands made by dipping strawboard into crankcase drainings containing a small amount of lampblack were placed on the same trees with beta-naphthol-treated half bands, and with untreated half-bands. The oil-treated bands captured more larvae than the untreated

Table 2.—Percentage of codling moth larvae in different types of strawboard bands on the same apple trees, Staunton, Virginia, 1938 and 1939.

YEAR	TYPES OF HALF-BANDS	LARVAE AND EMPTY COCOONS IN EACH TYPE OF BAND	
		Number	Per Cent of Total
1938	Beta-naphthol-treated	902	73.9
	Untreated	319	26.1
1939	Beta-naphthol-treated	214	59.6
	Untreated	145	40.4
1939	Beta-naphthol-treated	128	57.7
	Oil-lampblack-treated	94	42.3
1939	Oil-lampblack-treated	249	58.7
	Untreated	177	41.3

bands but fewer than the beta-naphthol bands. The darker color of the oil-treated bands would make them more attractive as cocooning places. The observation of Worthley (1934) that codling moth larvae are quickly paralyzed when they enter freshly treated beta-naphthol bands may explain the greater catch in these bands, since the habit of the larvae of wandering about before selecting a final cocooning place tends to become a one-way migration to treated bands.

PERCENTAGE OF LARVAE IN EACH OF TWO TREATED BANDS.—Steiner (1929) reported that where there was little or no litter under apple trees most of the codling moth larvae that left fallen fruit returned to the trees to cocoon and that the lower of two corrugated strawboard bands on the same tree captured as many larvae as the upper one. Van Leeuwen (1929) found that one-third of the larvae cocooned in the lower of two burlap bands separated by a sticky barrier. Eyer (1937) found that 57 per cent of the larvae came down the trees to the bands, and Cutright (1937) obtained similar results.

In 1938 three treated strawboard bands were placed around the trunk of each of eight apple trees. Isolated clumps of grass were the only vegetation under these trees. About one-third of the larvae in these bands were in the bottom band (Table 3). In 1939 two treated bands were placed around the trunk of each of eight apple trees. Strips of cotton batting 2 inches wide were wrapped around the trunk between the bands and tied with string. The cotton above and below the string was then pulled outward and extra cotton was pushed under the band at each depression to form a barrier. The barriers were renewed occasionally by rubbing the matted cotton. New barriers were placed on the trees before the second-brood larvae began to leave fruit. The relative numbers of larvae in the upper and lower bands (Table 3) was practically the same as in 1938 when three treated bands were used. It is evident that many of the larvae that leave fallen fruit return to the tree to cocoon if there is not much litter beneath the trees.

DISTRIBUTION OF CODLING MOTH LARVAE ON APPLES TREES.—Headlee (1929), using caged apple trees, obtained 91 per cent of codling moth emergence from the region of the trunks and larger branches, but it must be noted that this cage included all of the rough-barked branches. Sherman (1933) reported that 77 per cent of the surviving larvae in the spring were below the crotches. Worthley (1934) found that 28 to 60 per cent of the larvae on unscraped and unbanded trees were on the trunks, while only 5 to 10 per cent of those on scraped and banded trees, exclusive of those in the bands, were on the trunks.

Table 3.—Percentage of codling moth larvae cocooning in each of two or more treated bands on the same apple trees, Staunton, Virginia, 1938 and 1939.

YEAR AND POSITION OF BAND	LARVAE AND EMPTY COCOONS IN EACH BAND	
	Number	Per Cent of Total
1938, Top band	779	52.6
Middle band	234	15.8
Bottom band	469	31.6
1939, Top band	210	61.8
Cotton barrier	7	2.0
Bottom band	123	36.2

During the examination of apple trees in 1938 and 1939 to determine the number of larvae and empty cocoons on them, note was made of the position of each one found. Sixteen trees which have already been described were examined each year. In 1938 eight of the trees had been banded with treated strawboard, three with untreated strawboard, and five had not been banded. The results (Table 4) showed only minor differences in the distribution of larvae on banded and unbanded trees,

although the total number found on unbanded trees was greater.

In 1939 eight of the trees had been scraped before banding and eight had not. The scraped trees and four of the unscraped trees had been banded with treated band and the remaining unscraped trees had been banded with untreated band. In these examinations the trees were divided into five zones, designated as base, trunk, crotch, large branches, and small branches. The base was that part of the tree from about 6 inches above the surface of the soil to an inch below the surface. The trunk was the part between the base and the lowest crotch. Branches larger than $2\frac{1}{2}$ inches in diameter were classed as large. There were only slight differences in the distribution of the larvae on trees that had been scraped and those that had not been scraped, table 5. It is surprising that more than 88 per cent of the larvae were on the branches.

Table 4.—Distribution of codling moth larvae and empty cocoons on various parts of apple trees, Staunton, Virginia, Fall, 1938.

Type of Band	Larvae and Empty Cocoons Found			
	Total Number	Percentage on Each Region of Trees		
		Trunks	Crotches	Branches
Treated	331	20.6	5.1	74.3
Untreated	260	25.8	4.6	59.6
None	527	16.5	10.4	73.1

In the examination of these trees note was made of the type of shelter selected by each larva. Thus it was found that more than half of the larvae, table 6, had spun up in situations where they would not be dislodged by scraping the trees and where they would be safe from birds. In addition another 10 per cent were on the smaller branches and would not have been reached by the ordinary operation of scraping the trees. These facts may account for the slightness of the difference in catch on scraped and unscraped trees, table 1.

Table 5.—Distribution of codling moth larvae and empty cocoons on various parts of apple trees, Staunton, Virginia, Fall, 1939.

Type of Band	Larvae and Empty Cocoons Found					
	Total Number	Percentage on Each Region of Trees				
		Bases	Trunks	Crotches	Large Branches	Small Branches
Treated*	218	3.2	5.0	3.7	55.5	32.6
Treated†	143	1.4	7.0	4.9	48.9	37.8
Untreated†	168	0.6	5.9	3.5	51.2	38.7

* Trees scraped.
† Trees not scraped.

SURVIVAL OF LARVAE REMOVED FROM TREATED BANDS.—In 1937 and 1939 when the bands were examined all of the living larvae were removed and placed in battery jars with strips of corrugated strawboard in which they might make new cocoons. The larvae taken from treated bands and those taken from untreated bands were kept separate. In the spring of 1938 and the spring of 1940 records were kept of the emergence of moths from these lots of material. About 22 per cent of the larvae from treated bands emerged, while about 60 per cent of those from untreated bands did so (Table 7). Most of the discolored larvae taken from the treated bands did not begin new cocoons, but died in the bottoms of the battery jars or in the corrugations of the strawboard, from which their bodies could be shaken in large numbers. Some of the

Table 6.—Codling moth larvae and empty cocoons found in various types of shelter on apple trees, Staunton, Virginia, Fall, 1939.

Parts of Trees	Larvae and Empty Cocoons Found			
	Number on Each Region of Trees	Per Cent in Each Type of Shelter		
		Scales of Loose Bark	Shallow Pruning Wounds	Deep Cracks and Decayed Spots
Bases	10	50.0	0.0	50.0
Trunks	31	67.8	3.2	29.0
Crotches	21	100.0	0.0	0.0
Large branches	277	40.4	14.5	45.1
Small branches	190	9.5	17.4	73.1
Entire trees	529	33.5	14.0	52.5

Table 7.—Percentage of codling moth larvae taken from treated and untreated strawboard bands that transformed and emerged, Staunton, Virginia, 1937–1938 and 1939–1940.

SOURCE OF LARVAE	SEASON COLLECTED	NUMBER OF LARVAE COLLECTED	PERCENTAGE EMERGING, FOLLOWING SPRING
Treated bands	1937	5,959	25.0
Untreated bands	1937	263	62.0
Treated bands	1939	2,303	15.6
Untreated bands	1939	189	59.3

larvae that were apparently normal when they were removed from the bands became discolored and sluggish. Very few of these discolored larvae ever pupated, although some of them were still alive as late as the middle of the following July. Apparently only those larvae that entered the bands during the last few weeks they were on the trees were able to complete their development. It is unlikely that many of these larvae would have been able to survive if they had been left in the bands until spring.

CODLING MOTHS OVERWINTERING ON THE GROUND.—Headlee (1929) obtained no emergence from the ground under caged apple trees, and (1932) only a negligible number of moths from leaves raked up under apple trees. Worthley (1932), found that 1.5 per cent of the larvae cocooned on the ground under well scraped and banded apple trees; but Steiner (1929) estimated that 20 per cent of the larvae that came into contact with the soil failed to return to the tree, but he found that few individuals survive the winter on bare soil or in sod or straw.

In the spring of 1938 the leaves and the vegetation, consisting of sparse grass, under two apple trees were raked up and placed under cages. A total of 298 larvae and empty cocoons had been found on these trees in the fall of 1937. The cages were examined frequently during the period that moths were emerging in the orchard and for about two weeks afterward, but no moths emerged in them.

In the spring of 1939 cheesecloth cages were constructed under two apple trees. These cages were put into place before emergence of spring-brood moths began and were kept under observation during the period of emergence of moths and for about three weeks after it ceased. Under the first tree isolated clumps of grass were the only vegetation. The cage covered half of the area beneath the tree but excluded the trunk. A total of 293 codling moth larvae had been found on this tree in 1938. Four codling moths emerged in the cage under this tree.

There was a heavy growth of poison ivy beneath the second tree, and this held the leaves that had fallen the previous fall. This tree had not been exemined the preceding year, but it had borne a good crop of fruit, and it is probable that it harbored as many worms as did the first. The cage covered one-fourth the area beneath this tree, excluding the trunk. No moths emerged in this cage.

In the spring of 1940 three cheesecloth cages were constructed beneath apple trees. Each cage covered one-fourth the area beneath the tree but excluded the trunk. On the first tree 121 larvae and cocoons had been found in the fall of 1939, on the second tree 147 larvae and cocoons, and on the third tree 100 larvae and cocoons. The soil beneath the first tree was almost bare, that beneath the second tree had a moderate cover of grass, that beneath the third tree was bare of vegetation but had a heavy cover of dead leaves. One moth emerged in each of the first two cages, but none in the third.

SUMMARY.—Beta-naphthol bands on mature, well scraped apple trees captured 69 to 83 per cent of the codling moth larvae that cocooned on those trees. The effectiveness of the bands was somewhat lower on unscraped trees, and untreated bands captured a smaller percentage of the larvae than treated. Beta-naphthol bands also captured more larvae than bands dipped in a mixture of oil and lampblack. When two treated bands, separated by a barrier, were placed on the same tree, the upper band captured about 60 per cent of the larvae, the lower ones about 40 per cent.

On mature apple trees 70 to 85 per cent of the larvae, exclusive of those in the bands cocooned on the branches, and more than half of the larvae were in locations where they could not be reached by

scraping the trees. Distribution of the larvae on the trees was little changed by banding or scraping of the trees.

Only 25 per cent of the living larvae removed from treated bands in the fall of 1937 completed their development and emerged the following spring, and only 15 per cent of those removed from treated bands in the fall of 1939 emerged the following spring. The emergence of larvae from untreated bands examined during the same years was, respectively, 62 and 59 per cent.

No codling moths emerged in cages placed over leaves raked up beneath heavily infested apple trees. Few moths emerged in cages placed over the soil beneath heavily infested trees.—1-7-41.

LITERATURE CITED

Cutright, C. R. 1937. Codling moth biology and control investigations. Ohio Agr. Expt. Sta. Bul. 583.

Eyer, J. R. 1937. Ten years' experiments with codling moth bait traps, light traps, and trap bands. N. Mex. Agr. Expt. Sta. Bul. 253.

Farrar, M. D., and W. P. Flint. 1933. Chemically treated bands. JOUR. ECON. ENT. 26(2): 364–73.

Headlee, T. J. 1929. An operation in practical control of codling moth in heavily infested district—third and final report. JOUR. ECON. ENT. 22(1): 89–97.

Headlee, T. J. 1932. The problem of codling moth control. JOUR. ECON. ENT. 25(3): 545–54.

Newcomer, E. J., A. R. Rolfs, and F. P. Dean. 1933. A practical test of chemically treated bands for the control of the codling moth. JOUR. ECON. ENT. 26(6): 1056–8.

Sherman, Franklin III. 1933. A summary of three years' experiments on the control of the codling moth in southwestern Michigan. JOUR. ECON. ENT. 26(2): 383–92.

Steiner, L. F. 1929. Miscellaneous codling moth studies. JOUR. ECON. ENT. 22(4): 648–54.

Steiner, L. F., and A. J. Ackerman. 1936. Large-scale test of orchard sanitation to control codling moth. JOUR. ECON. ENT. 29(4): 648–53.

Van Leeuwen, E. R. 1929. Life history of the codling moth in northern Georgia. U. S. Dept. Agr. Tech. Bul. 90.

Worthley, H. N. 1932. Chemically treated bands in Pennsylvania. JOUR. ECON. ENT. 25(6): 1133–43.

Worthley, H. N. 1934. A second report on codling moth bands in Pennsylvania. JOUR. ECON. ENT. 27(2): 346–52.

Worthley, H. N., and L. C. Marston, Jr. 1936. Preparing chemically treated bands for codling moth control. Penn. Agr. Exp. Sta. Bul. 330.

Control of Codling Moth with Arsenate of Lead and Certain Forms of Rotenone and Pyrethrum

B. G. PRATT, *New York, N. Y.*

It is the intention to present in this brief non-technical paper, data that should be of interest to all who have worked on the codling moth.

Judging by the number of papers presented annually on this subject, it is safe to say that no other insect, since the advent of the San Jose scale, has been the subject of more research and study, or has cost the fruit growers of this country as much in actual cash, to say nothing of the immense losses in production.

It is with pardonable pride that I point to the fact, that I contributed, as much as any other individual, to the final conquest of the once dreaded San Jose scale, for I personally made the first water-miscible petroleum oil ever made in this country, and I want to take this occasion to express my deep sense of gratitude to the many entomological friends who, 35 years ago, helped me to disprove two things which at that time were considered almost axiomatic. First, that oil and water would not mix and second, that an oil spray could not be made safe to apply to fruit trees, and I hope that with your help I may point the way to reducing the ravages of codling moth, if not to its final conquest.

For several years past both rotenone and pyrethrum, sometimes in combination with arsenate of lead, have been used against the codling moth. Theoretically they should greatly increase the kill, but actually the results have been only mediocre.

A few years ago, after a number years of research and experiment, a new base, or carrier for rotenone and pyrethrum was discovered. In this base the rotenone and pyrethrins are apparently enclosed in an oil globule which seems to have the effect

of greatly increasing their activity and penetration, also admitting of their use with the milder alkaline sprays, such as lime sulfur, flotation sulfur and standard sulfur fungicides without affecting their toxic properties. It is not compatible, however, with the higher alkaline sprays such as hydrated lime or homemade bordeaux.

This material which is known as *D-X*, makes a happy combination with arsenate of lead. The lead seems to become coated or impregnated with the rotenone and pyrethrins, thereby apparently increasing the toxicity of both the contact and residual poison. Furthermore, there are indications that it forms such a close union with the arsenate of lead that paralysis evidently takes place quickly, even if the insect is able to discard a mouthful of the poison.

I am quite sure that before giving you the results obtained against codling moth, you will be interested in the development of this spray which seems so remarkable even to me, after 35 years in commercial orcharding and study of insecticides.

In July 1937 Japanese beetles were observed on some Scotch broom in my yard. This is a shrub that remains green all winter. These were promptly sprayed with *D-X* and arsenate of lead. Frequent observations showed that this residue, apparently arsenate of lead was plainly visible for a period of 10 months of rain and winter snows. The last observation was made the following April just before leaving on a trip to South Africa.

This led to some very extensive experiments on the sticking properties of *D-X* and arsenate of lead, which indicated that the combination when dry was only slightly affected by rain.

During the year 1938 the Maryland Experiment Station conducted an extensive retardation program against the Japanese beetle. The results were reported in the JOURNAL OF ECONOMIC ENTOMOLOGY (Langford *et al.* 1939).

Among the number of sprays used were some 3,000 gallons of dilute *D-X* and arsenate of lead which stood at the head of the list for effectiveness. One application of 3 pints *D-X* and 2 pounds arsenate of lead protected apple and shade trees for the entire season, with only 5.4 per cent defoliation from the beetles, as against a range of 18 to 78 per cent defoliation under other control measures. This combination since then has been used extensively and successfully in Japanese beetle areas.

Naturally, this was followed by a number of practical tests on codling moth in several states with similar outstanding results. I will mention one typical example.

In a badly infested apple orchard, 32 rows of Baldwins with an average crop of 30 bushels per tree, were selected for 4 experiments of 8 rows each. All the blocks received the standard sprays up to the peak of the hatch of the first brood codling moth, consisting of arsenate of lead, a sticker and bentonite sulfur. For the peak of the hatch of the first brood codling moth the following combinations were used.

Block 1	*Block 2*
Lead Arsenate	Lead Arsenate
Lime	Rotenone
Sticker	Sticker
Bentonite Sulfur	Bentonite Sulfur
Block 3	*Block 4*
Lead Arsenate	Lead Arsenate
Lime	*D-X*
Fish Oil	No lime or fungicide
Sulfur	

Before the second brood, all trees were examined and all apples showing stings or entries were removed in picking bags and counted. Block 1 averaged from 60 to 100 stings and entries per tree. Block 2 from 40 to 60 stings and entries per tree. Block 3 from 60 to 80 stings and entries per tree. Block 4 from 2 to 6 stings per tree and practically no entries.

In 1940 this orchard of several thousand trees was used on a large scale experiment, with an adjoining check block. The regular schedule was followed with fungicides and cover sprays throughout the season, but at the peak of the hatch of the first brood codling moth 1.5 pints *D-X* and 3 lb. arsenate of lead were applied. However, in a block around the packing house where infestation was extra heavy, an additional spray of 1.5 pints *D-X* and 3 lb. arsenate of lead was added to the cover spray immediately preceding the peak of the hatch. This crop was from 95 to 98 per cent codling moth free. On the check block where the straight arsenate of lead schedule was followed there was only from 50 to 75 per cent clean fruit.

While these experiments cover only two years, they indicate clearly the value of

intensive first brood measures, and the possibility that when conducted on a sufficiently large scale, second brood infestation can be greatly reduced.

In the small block in 1939 there was a heavy second brood infestation from adjoining trees. In the large scale operations in 1940, many of the blocks needed no second brood spray, and received none. The use of such control measures on a sufficiently large scale may reduce our codling moth schedule to a few well timed applications as was the case 25 years ago.—11-27-40.

LITERATURE CITED

Langford, Geo. S., S. L. Crosthwaite, and F. B. Whittington. 1939. A review of co-operative Japanese beetle retardation work in Maryland. JOUR. ECON. ENT. **32**(2): 255–9.

Evidence for a Third Brood of the Grape Berry Moth, *Polychrosis viteana* Clemens, in the Great Lakes Region[1]

BRUCE D. GLEISSNER and HARLAN N. WORTHLEY, *Pennsylvania State College, State College, Pa.*

The grape-berry moth spends the winter as a pupa on the soil surface. It is enclosed in a characteristic leaf-fold cocoon, spun in sodden grape leaves beneath the vines during the preceding fall. Moth emergence begins at about the time of grape bloom, and first-brood eggs are laid in the blossom clusters and on the newly set berries. The resulting larvae feed on the blossoms and small berries, webbing them together and sometimes destroying the whole cluster. Full-grown larvae spin cocoons on the growing leaves, and the first-brood moths emerge over a period of a month to six weeks beginning in the middle of July. Second-brood eggs are laid on the berries, which the larvae enter and destroy. A single larva may ruin as many as five berries during the course of its development.

According to Dozier *et al.* (1932) there are two full broods and a partial third brood of larvae in Delaware. In the Erie-Chautauqua grape belt of western New York and Erie County, Pennsylvania, however, Johnson & Hammar (1912) reported one complete and a partial second brood of larvae each season. Goodwin (1916) found that the insect produced two full broods each season in several localities in Ohio. Ingerson (1920), reporting on several seasons of biological studies in the region of Sandusky, Ohio, showed that the seasonal cycle includes one complete brood and a partial second brood of larvae. This partial second brood was much more numerous, and caused many times more injury, than the first brood. Gentner (1925) suggested that in Michigan the insect may produce a partial third brood in a normal year, but he was not able to detect it in 1924. His conclusions were based on the fact that the very earliest cocoons of the second brood were spun early enough to allow emerged moths to give rise to a third brood of larvae. Eyer & McCubbin (1926) stated that in Erie County, Pennsylvania, there is a full first and a partial second and third brood each year, but they presented no experimental evidence.

The contradictory nature of the foregoing statements pertaining to the grape-berry moth in the Great Lakes region suggests the presence of factors that have not been fully evaluated. The purpose of this paper is to present evidence gained from investigations in Erie County, Pennsylvania, in 1939 and 1940, that may help to resolve the contradictions in previous reports. This evidence supports the statement that in this area the grape-berry moth produces a full first, a full second, and a partial third brood of larvae each season in vineyards growing on the lighter soil types such as gravels, gravelly loams and sandy loams, while the partial third brood is not produced, in some seasons at least, in vineyards on the heavier clay soils.

OBSERVATIONS IN 1939.—During the season of 1939 the major life history studies were conducted in the heavily infested Farver vineyard located on a heavy clay soil about two miles west of North East and one mile south of the Lake Erie shore.

[1] Authorized for publication December 19, 1940, as Paper No. 1011 in the Journal Series of The Pennsylvania Agricultural Experiment Station.

Supplementary and incidental observations were made in the Miller vineyard, located on a gravelly loam soil in a direct line one mile south of the Farver vineyard. In these and other vineyards mentioned, grapes of the Concord variety were used.

In an effort to find out where the insect overwintered, and to obtain material from which to observe spring-brood moth emergence, thin layers of soil taken from various areas in the Miller vineyard were washed through screens. With much labor 115 cocoons were obtained, about 80 per cent coming from the "trellis strip" of soil directly beneath the vines. These cocoons were removed to the insectary located at the Farver vineyard, where they were placed on the ground under a cheesecloth cage in the partial shade of a tree adjacent to the vineyard. Fifty-two moths emerged, the peak and mid-point of emergence falling on June 20. Grapes on light soils blossomed from June 8 to June 18, and on heavy soils from June 11 to June 22.

Moth activity in the Farver vineyard was followed through the use of bait traps. Eighteen quart-jar traps were hung from the top wire, about five vines apart, and charged with a solution containing

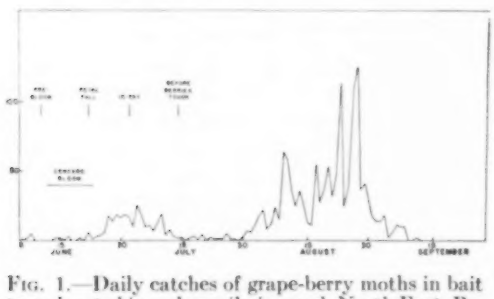


FIG. 1.—Daily catches of grape-berry moths in bait traps located in a clay soil vineyard, North East, Pa. 1939.

10 per cent by weight of brown sugar. Twelve of the traps were double, bait being replenished alternately in the two jars. As is the case with the codling moth, grape-berry moths entered these traps in significant numbers, the catches very evidently reflecting the status of moth emergence plus the effects of evening weather conditions. The records obtained are given in figure 1. Moths of the overwintered or spring generation were present from June 7 to about July 20, with the mid-point of abundance on July 3. First-brood moths, nearly five times as numerous as those of the spring brood, emerged largely during the month of August, with peak catches coming during the latter part of the

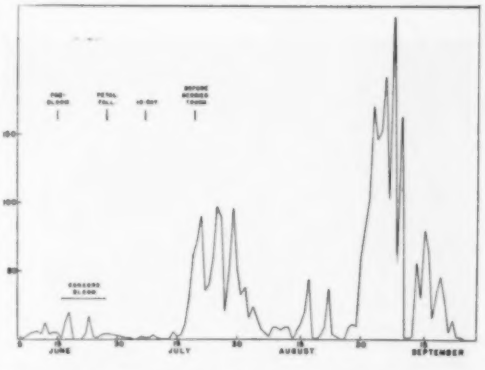


FIG. 2.—Daily catches of grape-berry moths in bait traps located in vineyard on gravely-loam soil, North East, Pa. 1940.

month, and the 50 per cent point of abundance on August 21.

In the insectary-rearing of first-brood moths from larvae in grapes picked in several vineyards growing on a wide range of soil types, the 50 per cent point of emergence fell on August 9, 11 days before the mid-point of the bait trap catches. It was not suspected that the presence in the collections of many larvae from vineyards on light soil was in part responsible for this difference, which was attributed in part to a possible effect of rearing under somewhat abnormal conditions in the insectary, and in part to weather unfavorable for moth flight at the time of peak emergence.

DEVELOPMENT ON GRAVELLY LOAM SOIL IN 1940.—The growing season started late in 1940 due to sub-normal temperatures during a very wet spring. On all soil types, Concord grapes blossomed about 9 days later than in 1939. Berry-moth development was watched in the Farver vineyard and in the Young vineyard, which was on gravelly loam soil located about one-half mile south of the lake and a mile west of North East. The two vineyards were roughly a mile apart. Bait pails were operated in an unsprayed area of the Young vineyard from the last week in May to the last week in September. The records, shown in figure 2, revealed three distinct periods of moth

flight. The first involved 136 moths of the overwintered generation, with emergence centered about June 18. Arbitrarily placing the flight limits at July 5 and August 13, the second period involved 907 first-brood moths, with the 50 per cent point

FIG. 3.—Tray of grapes infested with grape-berry moth larvae placed above one containing fresh grape leaves on which cocoons are spun.

falling on July 25. A distinct break in the record was followed by the largest catches of the season, totaling 2,017 moths, with the mid-point on September 5. It seems clear that these moths were adults of the second generation. Peak flights of this brood were delayed some days by cold nights during the last week in August.

Records of egg deposition by moths of the overwintered brood were not obtained, for the eggs are not readily observed among the blossom clusters. During the later periods of moth activity, however, counts were made of the number of eggs on 25 clusters taken at random in the baited area of the Young vineyard. Samples were taken over a sufficient period of time to indicate the oviposition peaks. The counts are presented in table 1.

The count of September 20 revealed a potential infestation of 19 worms per cluster, capable of destroying 95 berries. The average cluster contained less than 50 berries.

As a check on the accuracy of bait-trap records in revealing the development of the broods, moth-emergence records were obtained by the methods developed in 1939. Cocoons spun the previous fall, and overwintered on a gravelly loam soil, were covered with a cheesecloth cage. The 50 per cent point of moth emergence in this cage fell on June 18, coinciding with the mid-point of moth catch in the Young vineyard. On two dates after the hatching of first-brood eggs, random samples of grape clusters were taken from the vineyard to the insectary, located in 1940 at the nearby Kebler vineyard, and placed in trays, the bottom of which was closed with 4-mesh wire screen. These were racked alternately with trays containing fresh, clean grape leaves. This arrangement is shown in figure 3. Mature larvae dropped among the leaves, on which they spun cocoons. These were recorded and removed daily, and placed in screen-covered glass provision jars protected from direct sunlight. Moths emerging in these jars were counted and removed daily.

Table 1.—Oviposition peaks for first and second brood grape-berry moths. Young vineyard, North East, Pa. 1940.

Sampling Date	Number of 2nd Brood Eggs on 25 Bunches	Sampling Date	Number of 3rd Brood Eggs on 25 Bunches
July 24	15	Sept. 1	94
25	16	3	155
26	14	5	211
27	45	7	306
29	42	10	423
31	62	20	480
Aug. 3	129		
6	103		

Moth-emergence records obtained by the methods outlined conformed closely to the records of bait-pail catch. The 50 per cent point and peak of first-brood moth emergence and of the bait-trap catches of first-brood moths came on July 25. Further collection and rearing of second-brood larvae revealed a mid-point of moth emergence on August 28, eight days before the delayed peak of second-brood moth catch in the Young vineyard. Insectary records and counts made in the vineyard both showed that about 17 per cent of the second-brood pupae failed to produce moths, but remained to hibernate as pupae.

DEVELOPMENT ON CLAY SOIL IN 1940.—Certain studies were made in the Farver vineyard for comparison with the records obtained in the Young vineyard. At intervals after the hatching of first-brood eggs was complete in the Farver vineyard,

grape clusters were picked at random as in the young vineyard. In the insectary, moths were reared separately from these samples. The record of moth emergence from grapes obtained in both vineyards is given in figure 4. The mid-point and peak of moth emergence came 18 days later in the material from the clay-soil vineyard than in that from the grapes grown on the gravelly loam soil. As may be seen by comparing figures 1 and 4 B, there is a close correspondence between the first half of the first-brood moth flight record of 1939 and the moth-emergence record of 1940, in the Farver vineyard.

An attempt was made in a preliminary way to reveal variations in the stage of berry-moth development by making random collections of grape clusters from several vineyards on the same day, counting the eggs found, dissecting out the larvae, and assigning these to the proper instar through measurements of head-capsule width. Collections were made on August 14 in the Farver vineyard, in the Young vineyard, and in the adjacent and similar McDonald vineyard. Eggs constituted nearly half the individuals recovered from the Farver vineyard collections, but they were absent from the clusters taken in the two vineyards on gravelly loam soil. Larvae, especially those in the younger stages, were not recovered in numbers sufficient to allow a sure judgment as to the exact number of instars and the width limits of the head capsule in each. However, while larvae nearly full grown predominated in the collections from both light-soil vineyards, the average size was much smaller in the material from the Farver vineyard. Furthermore, at the time of collection no cocoons could be seen on the leaves in the clay-soil vineyard, while they were readily observed in both blocks on gravelly loam soil.

Taken in connection with the other records obtained, these observations indicated a more advanced stage of berry-moth development on the lighter soils. Samples taken three days later from grapes on gravelly loam soil in the Minor vineyard, Sheridan, New York, showed a high proportion of mature larvae, many cocoons, and a few eggs, presumably of the third brood.

The cocooning of late-season larvae collected in the Farver and Young vineyards presented an interesting contrast. In material from the former vineyard the cocooning of second-brood larvae began in late August, reached a peak one month later, and gradually subsided to a few stragglers by mid-October. Third-brood larvae from the Young vineyard started to cocoon on September 21. The numbers

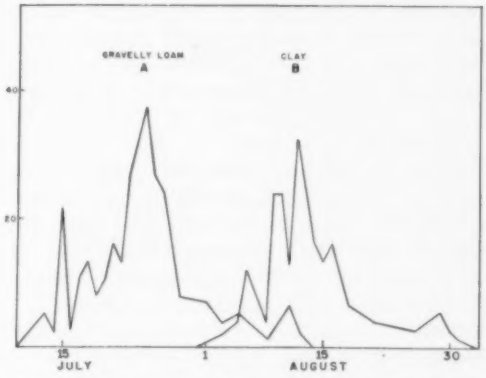


FIG. 4.—Emergence of first-brood grape-berry moths in 1940, showing advanced development in vineyard on light soil.

increased rapidly until checked suddenly by cold weather on October 14. Cocoon formation then dropped off sharply and ended on October 29. It seemed evident that whereas nearly all second-brood larvae in the clay-soil vineyard were successful in entering hibernation, many third-brood larvae in the light-soil vineyard perished before spinning cocoons. This is a possible explanation of the common observation that berry-moth infestations tend to persist in clay-soil vineyards, while they are erratic in grapes growing on lighter soils.

DISCUSSION.—The discovery in 1940 that the method of insectary rearing gave moth-emergence records closely comparable to the bait-trap catches of moths in the vineyard gave new meaning to the 1939 moth-emergence records. It became evident that the early peak of emergence from the reared material in 1939 had been due not to faulty rearing technic, but to the lumping of collections of wormy grapes from all vineyards, early and late. It appeared that records taken in the Farver vineyard gave no adequate picture of the situation in the Miller vineyard where, as shown by the 1940 records from the Young vineyard, a third brood of larvae must have developed during the harvesting period. The increasing worminess

of grapes as the harvest proceeded about North East during October, 1939, caused much comment and speculation. The 1940 records from the Young vineyard provided an adequate explanation in revealing a third brood of larvae.

Hall (1931), discussing the specific heat of common soil types in a saturated but well-drained condition, stated that "sandy soil requires only about half as much heat to raise its temperature by a given amount as would be needed by a peaty or clay soil . . . if the clay or peat were inadequately drained . . . their specific heats would approximate more nearly that of water." Clay soils along the lake shore are more poorly drained than the lighter soils, and dry out more slowly in the spring and following summer rains.

It is natural to suppose, then, that berry-moth pupae in cocoons lying on a light, well-drained soil would produce moths earlier in the spring than those on a heavy, wet clay soil. The more rapid rate of development on the lighter soils throughout the growing season is aided, if not controlled, by a reversal of the process just discussed. Light soils lose heat faster than heavy soils. In the Young vineyard it was found that air temperature just below the level of the top trellis wire (where berry moths are most active) may rise as much as three degrees Fahrenheit from sundown to midnight. Thermograph records of air and soil temperature in vineyards will be required to evaluate fully the effects of heat on the seasonal development of the grape-berry moth.

The sharp differences in berry-moth development that appear in the records presented should not be emphasized. In the lake shore region of Erie County, Pennsylvania, vineyards are found on many soils intermediate between the lightest sand and the heaviest clay. In addition, slope, drainage, distance from the lake, and elevation all affect the seasonal development of the vineyards and of their inhabitants. The records reported perhaps approach the limits of variation in time and rate of berry-moth development as affected by vineyard-soil type. Taken in connection with spray schedules suggested by various investigators for the control of this insect, however, they suggest that soil type may determine to a large extent the timing of berry-moth spray applications in a given vineyard.

The dates of spray applications commonly timed by vine development are recorded in figures 1 and 2. The preblossom spray was applied too early in the Farver vineyard in 1939 to afford any protection against the attack of first-brood larvae. The petal-fall and 10-day sprays, however, were timely. The last regular application, made just before the berries touched, or about three weeks after petal-fall came at a time when its sole benefit was the placing of a "film of protection" between the berries to stop the later passage of larvae.

The Young vineyard in 1940 presented a different situation. The pre-bloom spray was timely for early first-brood larvae, and the petal-fall application for later ones. The 10-day spray, however, fell between the broods, and did little good. The "before touching" spray was timely for the first attack of second-brood larvae. The counts made in comparisons of spray materials and schedules in the two seasons support these statements.

These differences in spray timing with respect to vine development in vineyards on different sites serve to explain the variety of published recommendations for grape-berry moth spraying in the Great Lakes region. They indicate further that even in restricted localities it may be impossible to make blanket recommendations, but that intelligent spraying may require careful observation of the seasonal development of the berry moth in the individual vineyard. Adequate timing and application of early sprays may obviate the necessity for late applications of nonresidue materials. Existing records indicate, however, that where these become necessary careful local timing will be required, with applications directed against the second brood in clay soil vineyards, and against the third brood in those on lighter soils.-1-7-41.

LITERATURE CITED

Dozier, H. L., L. L. Williams, and H. G. Butler. 1932. Life history of the grape-berry moth in Delaware. Del. Agr. Expt. Sta. Bul. **176.**

Eyer, J. R., and W. A. McCubbin. 1926. Grape insects and diseases. Penna. Dept. Agr. Gen. Bul **433.**

Gentner, L. G. 1925. Some important grape insects. Mich. Agr. Expt. Sta. Spec. Bul. **148.**
Goodwin, W. H. 1916. The grape-berry worm (*Polychrosis vitaena* Clemens). Ohio Agr. Expt. Sta. Bul. **293.**
Hall, A. D. Sir. 1931. The Soil. E. P. Dutton and Co. New York. 4th ed. p. 159.
Ingerson, H. G. 1920. Life history of the grape-berry moth in northern Ohio. U.S.D.A. Bul. **911.**
Johnson, Fred, and A. G. Hammar. 1912. The grape-berry moth. U.S.D.A., Bur. Ent. Bul. **116,** Part II.

Radioactive Tracer Methods for Determination of the Disposition of Arsenic in the Silkworm[1,2]

L. B. NORTON, *New York Agricultural Experiment Station, Geneva*
and ROY HANSBERRY, *Cornell University, Ithaca, N. Y.*

One of the least understood problems in insect toxicology is the behavior of insecticides after they have entered the insect's body. The difficulty in obtaining such information has been due primarily to the lack of methods of chemical analysis sensitive and accurate enough to determine the minute quantities of material involved. Campbell & Lukens (1931) reported some preliminary experiments in which they fed silkworms a measured dosage of lead arsenate containing a radioactive lead isotope, and determined the amount of elimination and the solubility of the lead in the digestive system by measurements of the radioactivity of the samples as determined by an electroscope. This technique permitted the accurate determination of amounts of lead far below the limits of chemical analysis, and made it possible to work with single insects. The behavior of arsenic is of still greater interest than that of the lead, since the major part of the toxicity of lead arsenate is considered to be due to its arsenic content. It was impossible at that time to to apply a similar method to arsenic, since no radioactive isotope of arsenic was then known. Recently, however, radioactive isotopes of a large number of common elements have become available through the development of methods for preparing them artificially, and they have proved very successful in the solution of many biological problems. The present experiment was designed to test the possibilities of radioactive arsenic for following the behavior of arsenic in insects.

PREPARATION OF MATERIAL.—The method employed in preparing the material for use will be given in some detail because of the broad applicability of the radioactive tracer method to the solution of problems in insect toxicology.

The original radioactive arsenic was prepared by bombarding about 0.1 g. of powdered metallic germanium with protons in the cyclotron. The resulting sample contained two radioactive isotopes, of which the one remaining in appreciable amounts at the time of the measurements had a half-life of 17 days. The bombarded sample, now containing a very minute quantity of the radioactive arsenic with a large amount of the unchanged germanium, was dissolved in hydrochloric acid and hydrogen peroxide, and 7.5 mg. of ordinary arsenic added in the form of a solution of Bureau of Standards arsenic trioxide. This dilution with non-radioactive arsenic was necessary to give the proper range of sensitivity for the quantities to be used for the measurements, and to furnish sufficient material with which to work. The solution was diluted to 300 cc. with hydrochloric acid and water to give a final concentration of about 25 per cent of hydrogen chloride. The unconverted germanium was removed from the arsenic by distillation from this solution through a fractionating column in a current of chlorine (Dennis & Johnson 1923). The residue from the distillation was fumed with nitric and sulfuric acids to remove the hydrogen chloride and chlorine, and the arsenic recovered as the free element in a Marsh apparatus, with the use of fine

[1] Approved by the director of the New York State Agricultural Experiment Station as Journal paper No. 414, December 20, 1940.

[2] The investigation was made possible by the cooperation of the following: Professor A. W. Laubengayer of Cornell University, who furnished the germanium used for the preparation of the arsenic; Dr. S. N. VanVoorhis of the Department of Physics of the University of Rochester who prepared the radioactive samples with the cyclotron; Dr. William Bale and co-workers at the University of Rochester Medical School who furnished guidance and assistance in the preliminary work; and Dr. L. A. Maynard of Cornell University, who loaned the Geiger-Müller counter used in the later determinations. Special recognition is due to Dr. C. L. Cottrell of the Department of Physics, Cornell University, who constructed the Geiger-Müller counter used in the final investigation, assisted in the determinations, and suggested and made the photographic records.

granulated zinc and 20 per cent sulfuric acid. Direct weighing of the deposit showed the recovery to be complete. The arsenic was dissolved in 30 per cent hydrogen perioxide to form arsenic acid, which was diluted to 25 cc.

To 15 cc. of the arsenic acid solution was added the calculated amount of 0.1 N sodium hydroxide to form disodium arsenate. This solution was diluted to 25 cc., giving a concentration of 0.18 mg./cc. of elemental arsenic. A portion of this solution was diluted 100 times and reserved as a standard for the subsequent measurements.

The remaining 10 cc. of arsenic acid was added to an excess of boiling saturated calcium hydroxide. The precipitate of basic calcium arsenate was digested in the hot solution, then centrifuged out, washed with several portions of water, and dried.

An equivalent amount of lead nitrate solution was added to 10 cc. of the sodium arsenate solution, and the precipitate of lead arsenate centrifuged out, washed, and dried. It is possible that the lead arsenate was somewhat more basic than pure dilead arsenate because of the extreme dilution of the solutions used for its preparation.

For the higher dosages, the lead and calcium arsenates prepared as above were diluted with known amounts of ordinary lead and calcium arsenate in order to furnish sufficient material for the tests.

MEASUREMENT.—The insect samples were prepared for analysis by a short digestion in concentrated nitric acid. No attempt was made to destroy the organic matter completely, since it did not interfere appreciably with the measurements. The boiling was continued only until the sample became practically homogeneous. The digestions were carried out in small pyrex test tubes calibrated at 1.5 and 3 cc., and the solutions diluted to one of these volumes after digestion. The final measurements were made on 1 cc. samples pipetted from these solutions.

The radioactivity measurements were made with a Geiger-Müller counter, using an apparatus and technique similar to that of Bale *et al.* (1939). Accurate fitting of the sample tube to the counter tube made it possible to use 1 cc. samples for each determination. The activity of each sample was observed over at least two periods of two or three minutes each. Portions of the standard dilute sodium arsenate solution were measured in the same manner each day and the activity of the standard plotted for the whole duration of the experiment. The arsenic content of each sample could then be determined by comparison of its activity with that of the standard interpolated to the same time by means of the curve.

The precision of the determination decreases as the sample ages, since the radioactivity decreases by half every 17 days. Tht precision during the experimental period was of the order of ± 0.03 microgram (0.00003 milligram) of arsenic or better, amounting to about 1 per cent of the average amount determined per sample. There was a more or less constant error introduced by the absorption of some of the radiation by the acid left from the digestion procedure, and particularly by the heavier elements from the insect materials. This absorption was found to cause a loss of about 12 per cent for a single measurement on a complete insect, in excellent agreement with the total recoveries of 83 to 89 per cent obtained with the experimental insects as shown later in table 1. The high and consistent recoveries from the insects indicate a high degree of accuracy in the individual analyses and the probable absence of any consistent source of error other than the absorption of the radiation.

TREATMENT OF INSECTS.—Silkworms were used for all of the experiments because of their size, ease of rearing, and sensitivity to arsenicals. Individuals were chosen having as nearly as possible the same weight, averaging about one gram. After the insect was weighed, the calculated dose of the arsenical was injected directly into the foregut by means of a hypodermic syringe fitted with a calibrated micrometer (Trevan 1922). The disodium arsenate was injected directly as the solution previously described, and the lead and calcium arsenates as suspensions in starch paste.

After injection, the insects were placed in individual glass dishes lined on the bottom with filter paper. A fresh portion of mulberry leaf was periodically supplied to each insect. The feces were collected and analyzed every three hours for the first twelve hours, then after two six-hour periods, and finally just at the time of dis-

Table 1.—Disposition by the silkworm of arsenic from different arsenates.

Sample	Hours After Injection	Micrograms Arsenic Recovered					
		Na low alive	Na low dead	Ca low alive	Ca high alive	Pb low alive	Pb high dead
Feces	3	2.40	2.06	2.01	8.75	2.98	0.62
Feces	6	4.20	2.24	4.03	18.29	6.07	20.84
Feces	9	1.06	0.70	1.23	4.87	0.95	2.71
Feces	12	0.81	0.45	0.29	3.60	0.20	1.25
Feces	18	0.69	0.84	0.31	8.44	0.04	—
Feces	24	0.50	0.30	0.06	2.21	0.00	—
Feces	48	1.39	0.13*	0.04	1.08	0.01	—
Regurgitation		1.20	2.04	0.00	0.00	0.00	3.20
Retained (blood)†		1.17	1.89	0.10	0.41	0.19	0.92
Retained (tissue)†		1.89	4.14	0.25	1.99	0.10	1.86
Retained (gut)†		5.97	6.15	1.92	10.55	1.15	18.27
Total recovered		21.08	20.94	10.24	60.19	11.68	49.67
Total injected		23.6	23.7	12.3	68.9	13.4	57.9
Per cent total recovery		89	88	83	87	87	86

* At time of death, 26 hours.
† At time of death or recovery.

section. In one series receiving sodium arsenate, each separate pellet was collected and analyzed. If any regurgitation occurred, it was absorbed by the filter paper, which was then digested and analyzed. The condition of each insect and the amount of feeding were observed at intervals.

As soon as an insect died, it was dissected for analysis. Those which recovered were dissected after 48 hours from the time of injection. Each insect was divided into three samples: the blood, most of which was drained out by clipping off a proleg, and the rest recovered by rinsing off the tissues after dissection; the gut, which was analyzed as a whole, including contents; and all of the remaining tissues taken together. The silk gland was ordinarily included with the miscellaneous tissues, but in a few cases it was analyzed separately. Each of the samples was weighed before analysis, the weight of the blood being obtained by difference.

Results.—In table 1 are presented the quantities of arsenic eliminated and retained by the silkworms for each of the treatments used. Each figure represents the mean value for all the insects receiving the same treatment, omitting only those which were subjected to obviously complicating factors such as pupation before the end of the observation period, and those from which any samples were lost or omitted from the analysis. Seven individual insects are represented in the "Na low alive" group, thirteen in the "Na low dead" group, and six in each of the other groups. Those groups designated as "low" received 0.01 to 0.02 milligram of arsenic per gram of insect, and the "high" groups 0.06 milligram per gram, in the form of the sodium, calcium, or lead arsenate. The graphs used in the subsequent discussion are all derived from the data of table 1.

It should be noted that the two different groups for each material do not represent exactly corresponding toxicological effects. The two sodium arsenate groups show the results from identical amounts close to the median lethal dose, the two calcium groups from two different sublethal doses, and the lead groups from one sublethal and one complete lethal dose.

Elimination of Arsenic.—The progress of the elimination of the arsenic from

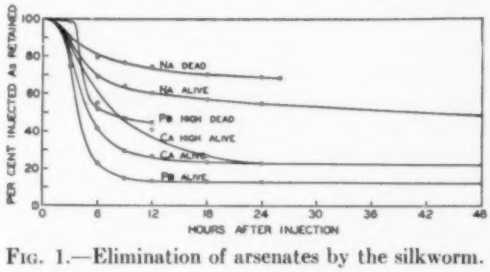


Fig. 1.—Elimination of arsenates by the silkworm.

the insects is plotted in figure 1. In order to avoid differences due to variations in insect weight, dosage, and analytical recovery, the amount of arsenic recovered is arbitrarily taken as equal to 100 per cent of the amount injected, and the separate

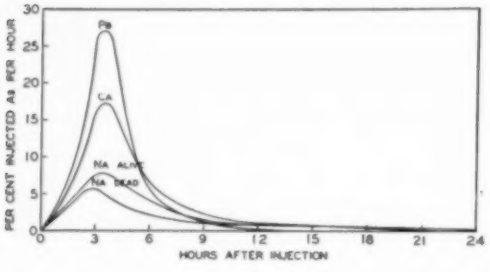


FIG. 2.—Rate of elimination of low dosages of arsenic by the silkworm.

items plotted as percentages of this amount. Equal percentages on the figure therefore do not necessarily represent equal quantities of arsenic, but equal proportions of the original arsenic content of the insect.

All of the curves are very similar in form. The elimination of each material is very slight for the first hour, the major part takes place during the next few hours, and finally the arsenic content of the insect levels off and remains practically constant for a long period. These changes are shown more clearly in figure 2, in which the rates of percentage loss of the low dosages are plotted against the time. The rate shows a sharp maximum at about 3.5 hours, this time being practically independent of the material. This effect is probably due to the almost instantaneous injection of the entire dose of the arsenical, so that the unabsorbed portion is mechanically carried through the gut more or less as a unit. The time of the maximum rate of elimination of arsenic agrees closely with the three hours reported by Shinoda (1931) as necessary for food to travel through the digestive system of the silkworm under normal conditions.

Although the maximum rate of elimination occurs at the same time for the different arsenicals, it is apparent from figures 1 and 2 that both the rate itself and the final extent of the arsenic elimination are dependent upon the composition of the arsenical. The sodium arsenate is excreted more slowly and to a smaller extent than the others, as might be expected from its greater solubility and therefore greater availability for absorption by the gut wall. The calcium arsenate shows a slower and less complete elimination than the low dose of lead arsenate, which should be more soluble in the alkaline contents of the midgut. This discrepancy may be due either to the possible presence of the less soluble basic lead salt, as already mentioned, or to a possible difference in the manner of absorption of the two arsenicals to be discussed later. The high dose of lead arsenate showed a somewhat abnormal course of the elimination because of the violent toxic effects on the insect. Partial paralysis delayed the beginning of process and almost total inactivity later lowered the final extent of arsenic loss.

It is apparent that the absorbed arsenic is firmly fixed in the insect tissues, since the elimination of arsenic nearly ceased while there was still a considerable amount of arsenic remaining in the body. Even this slight remaining excretion was dependent upon the composition of the arsenical, however. Although all the rates were very low after the expulsion of the unabsorbed material, those compounds which initially were eliminated most slowly and incompletely showed the highest final rate of elimination of absorbed arsenic. The present data are not exten-

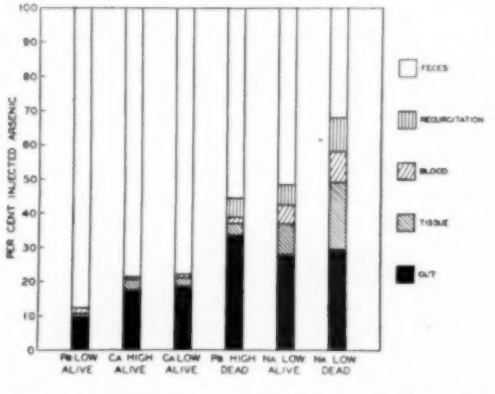


FIG. 3.—Final disposition of arsenic by the silkworm at time of death or recovery.

sive enough to determine whether the concentration of residual arsenic alone determines this final rate or whether the different arsenates show individual effects.

The toxic effect of the arsenicals used was closely related to the extent of their

elimination, as was previously noted by Cook & McIndoo (1923). In general, those materials absorbed most completely showed the most pronounced effects. In the case of the two groups given the same dosage of sodium arsenate, the extent of the elimination of arsenic from the survivors is greater than that from those killed. With such an intermediate dose of a single arsenical, the fate of an individual insect apparently depends upon the extent to which it is able to eliminate the arsenic without absorption.

FINAL DISPOSITION.—The final disposition of the arsenic at the time of death or recovery is plotted in figure 3. The arsenic is plotted in terms of percentage of the initial dose as before. It will be noted that the greater toxic effects of those materials showing the greatest proportion of absorption were accompanied by the regurgitation of appreciable amounts of arsenic.

Of the total amount of arsenic left in the insect, a greater proportion was left in the gut than in the other portions analyzed. O'Kane & Glover (1936) observed the same effect in studies of the absorption of arsenic through the integument of the American cockroach. Leiby,[1] using histological methods to study the toxicity of arsenic in the cotton boll weevil and the Mexican bean beetle, found the most pronounced effect on the tissues to be a breakdown of the wall of the midgut. The arsenic in the present investigation was assumed to be largely in the wall of the gut and not in the gut contents because arsenic had nearly ceased to be present in the feces at the time of the analyses. The radiophotographs shown later support this assumption, and indicate further that the major part of the arsenic present in the gut as a whole occurs in the wall of the midgut. There was little difference in the proportions of arsenic in the gut of insects receiving the high lead and the sodium arsenate treatments. These amounts, however, were higher than those from the calcium doses, which in turn were higher than those from the low lead dose.

The proportions of arsenic in the blood and tissues followed the same order as those in the gut, with one exception. The sodium arsenate showed a much higher relative proportion in the blood and tissues. It is interesting to compare the amount of arsenic in the blood and tissues with the total amount absorbed, which must originally have been taken up by the gut. The percentages of the absorbed arsenic transferred to the blood and tissues are shown in table 2. The arsenic absorbed from sodium arsenate is transferred more completely in those insects which were killed than in those which survived. Both of these groups showed more complete transfer than either of the insoluble arsenates, between which no significant difference appeared. The mobility in the insect body of arsenic from sodium arsenate is apparently greater than that from either lead or calcium arsenate. It also appears probable that the toxic effects are not limited to the arsenic in the gut alone.

Table 2.—Transfer of absorbed arsenic to blood and tissues.

TREATMENT	PER CENT ARSENIC TRANSFERRED
Na low alive	34
Na low dead	50
Ca low alive	15
Ca high alive	19
Pb low alive	20
Pb high dead	13

CONCENTRATION.—All of the discussion so far has been concerned with proportions or ratios of amounts. The actual concentrations in milligrams of arsenic per gram of insect material are given in table 3. Because of the varying weights of the parts from the different insects, these quantities are not strictly proportional to the quantities of arsenic per single insect part as given in table 1, but their order is the same throughout when any significant differences exist.

Table 3.—Mean concentration of arsenic in insect parts.

TREATMENT	MILLIGRAMS ARSENIC PER GRAM IN		
	Blood	Tissue	Gut
Na low alive	0.0023	0.0048	0.0136
Na low dead	0.0056	0.0118	0.0154
Ca low alive	0.0003	0.0006	0.0032
Ca high alive	0.0014	0.0060	0.0195
Pb low alive	0.0006	0.0002	0.0016
Pb high dead	0.0034	0.0064	0.0571

The concentrations of arsenic in the gut for the most part paralleled the toxic effects of the different treatments. The high

[1] Unpublished manuscript read at the 1938 meeting of the Entomological Society of America.

lead dose showed the greatest concentration of arsenic, and the low lead and calcium doses the least. The individuals killed by sodium arsenate had a higher concentration than the survivors. There was one discrepancy: the high dose of calcium arsenate gave a higher concentration in the gut than either of the sodium arsenate groups, although the physiological effect was less.

The concentrations in the tissue were also in approximately the same order as the toxic effects, but again discrepancies

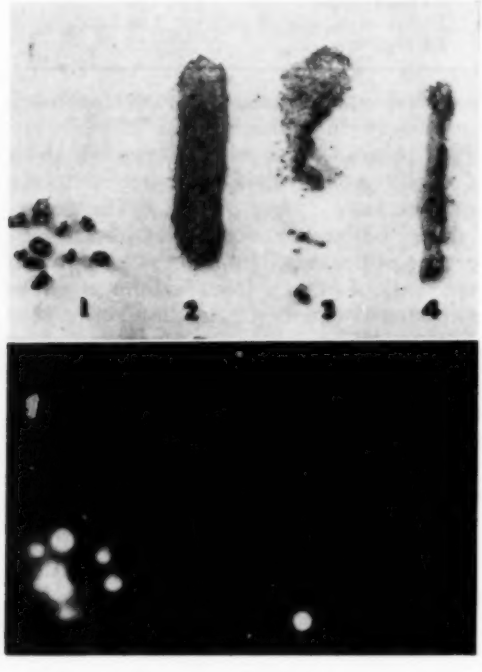


FIG. 4.—Photographic detection of radioactive arsenic. Ordinary photograph of insect parts above. 1.—Pellets; 2.—Cuticle and tissue; 3.—Contents of gut; 4.—Gut. Effect of rays from radioactive arsenic content below.

appear. The high lead dose gave a lower concentration than the lethal sodium dose, although the effects were more violent. The relatively ineffective high calcium dose gave almost as great a concentration as the high lead dose.

The concentrations in the blood were in the same general order as those in the gut and tissues, but these concentrations varied so greatly among individual insects that the differences cannot be considered significant.

No appreciable amount of arsenic was found in the silk glands when those parts were analyzed separately.

In general, the concentrations of the arsenic in the different parts of the insect appear to be related to the toxic effects, but the arsenicals apparently show individual differences in addition to the concentration effect.

PHOTOGRAPHIC DETECTION.—A few of the insects treated with the radioactive materials were dissected and the separated tissues spread out on a glass plate. A photographic process plate was laid on these tissues, protected and separated from them by a thin sheet of aluminum foil. The weakness of the radiation made an exposure of about two weeks necessary. One of the typical plates is reproduced in figure 4, along with an ordinary photograph of the dissected parts in position. This insect was injected with 0.02 mg./g. of arsenic as sodium arsenate and dissected after four hours.

The photographic results show qualitatively the same effects as the quantitative measurements. A few of the pellets show extremely high activity; others much less. The gut contains much more arsenic than the tissues. In addition, some effects are apparent which are not established by the other measurements. The gut contents, separated from the gut tissue, show no appreciable arsenic content, with the exception of one highly active pellet from the rectum, even after only four hours. This was previously only assumed from the low rate of further elimination. As mentioned before, it appears that most of the arsenic in the gut is concentrated in the midgut wall.

DISCUSSION.—A number of items in the present experiments demand some explanation of the behavior of these arsenicals other than a simple absorption of soluble arsenic and its subsequent toxic effect on one or more parts of the insect. Among these items are the differences in the amount of transfer from the gut to the rest of the body of arsenic from sodium arsenate as compared with that from the other arsenicals, the lack of toxicity of calcium arsenate in spite of the high concentration of arsenic absorbed into the gut, and the high toxicity of lead arsenate in spite of the low concentration in the tissues. These results indicate that arsenic absorbed from lead arsenate may have a lower mobility in the body and possibly

a higher toxicity than that from sodium arsenate, and that arsenic absorbed from calcium arsenate may have a lower mobility and also a lower toxicity.

Exactly this behavior might be noted if the arsenic, instead of being absorbed as the simple arsenate ion, were absorbed in the form of more complex ions containing some of the metallic element in addition to the arsenic. Such more complex ions are known to exist in solutions of salts of this type. Campbell & Lukens (1931) noted that the silkworm absorbed appreciable amounts of lead from lead arsenate, which would agree with this hypothesis. If this hypothesis is correct, the amount of arsenic absorbed from the different arsenates would depend not only upon the amount of soluble arsenic produced in the gut, but also upon its composition. The mobility of the arsenic in the body after absorption would depend upon the complexity and solubility of these ions, those containing lead and calcium being less mobile. The ions would be expected to have different inherent toxicities, depending upon the nature of the elements combined with the arsenic. It is not unreasonable that the lead might increase the toxicity of the arsenic and the calcium decrease it, as compared with sodium. This mechanism is admittedly only a hypothesis, requiring further proof. It is in agreement, however, not only with the present results, but with all of the other known chemical and toxicological properties of the arsenates.

SUMMARY AND CONCLUSION.—Analyses of feces, regurgitation, blood, gut and tissue samples of silkworm larvae fed radioactive arsenic were made with a Geiger-Müller counter. On the basis of these analyses the following conclusions are drawn.

(1) Initial elimination of arsenic is more rapid and complete for insoluble than for soluble arsenates.

(2) The arsenates eliminated most completely tend to be least effective.

(3) The elimination of arsenic once absorbed is very slow, but is greatest for the most completely absorbed arsenates.

(4) The major part of the absorbed arsenic is found in the wall of the midgut.

(5) The transfer of arsenic through the gut to the rest of the body depends upon the original composition of the arsenical.

(6) The toxic effects of the arsenates are roughly parallel with the arsenic concentrations in the gut and other tissues, but certain exceptions are noted.

(7) The behavior of the arsenates can be explained on the basis of absorption as complex ions.

(8) Radioactive arsenic shows great promise as a tool for more accurate investigation of the toxicology of arsenic in insects.—1-6-41.

LITERATURE CITED

Bale, W. F., F. L. Haven and M. L. LeFevre. 1939. Apparatus for the Rapid Determination of β-Ray Activity in Solutions. Review Scientific Instruments **10**(6): 193.

Campbell, F. L., and C. Lukens. 1931. A Radioactive Indicator Method for Estimating the Solubility of Acid Lead Arsenate within the Alimentary Tract of the Silkworm. JOUR. ECON. ENT. **24**: 88–94.

Cook, F. C., and N. E. McIndoo. 1923. Chemical, Physical, and Insecticidal Properties of Arsenicals. U. S. Dept. Agr. Bul. **1147**: 1–57.

Dennis, L. M., and Johnson, E. B. 1923. Germanium V. Extraction from Germanium-Bearing Zinc Oxide. Direct Preparation of Germanium Dioxide Free from Arsenic. Detection of Minute Amounts of Arsenic in Germanium Dioxide. Jour. Am. Chem. Soc. **45**: 1380.

O'Kane, W. C., and L. C. Glover. 1936. Studies on Contact Insecticides XI. Further Determinations of the Penetration of Arsenic into Insects. N. H. Agr. Expt. Sta. Tech. Bul. **65**: 1–8.

Shinoda, O. 1931. On Carbohydrate Digestion in the Silkworm. Annot. Zool. Japon. **13**: 117–25.

Trevan, J. W. 1922. An Apparatus for the Measurement of Small Quantities of Fluids. Lancet (London) **202**(1): 786.

The Oklahoma State Board of Agriculture, on March 5, 1941, issued revised rules and regulations setting forth the general requirements for carrying on a nursery or floral stock business, and specifying the facilities required "to promote the conservation and to preserve the vitality of nursery stock," and the facilities required in the handling of cut flowers for sale.

Papers on "Plant Quarantines as Barriers to Interstate Trade," which were delivered before the Section on Plant Quarantine at the annual meeting of the American Association of Economic Entomologists at Philadelphia in December 1940, have been mimeographed and copies are available from the Division of Domestic Plant Quarantines, Bureau of Entomology and Plant Quarantine, Washington.

A New Fumigant, 1,1-dichloro-1-nitroethane

W. C. O'Kane and Howard W. Smith, *Durham, New Hampshire*

Recent development of a new method of nitrating methane, ethane, and others of this series has made the nitroparaffins available in quantity. Other and related processes have made an extended list of their derivatives available. While these compounds are produced largely for various industrial uses, some of them are of such nature as to suggest possible employment in the chemical control of insects.

In studies of the derivatives it was found that 1,1-dichloro-1-nitroethane gave interesting performance as a fumigant. Intensive experimentation with this compound has now proceeded for two years with results that continue to enlist interest.

As will be noted, one of the carbon atoms of this compound carries two chlorine atoms and one NO_2 group. The other carbon atom carries three hydrogens. Thus it might be suggested that one end of the molecule represents a toxic group, since the combination $C Cl_2 NO_2$ is known to be toxic, while the other end represents a fugitive group CH_3, which would assist in penetration of the gas and likewise in its disappearance on ventilation.

The material is liquid at all natural temperatures. It is colorless and has a specific gravity at 20° C., of 1.4153. It boils at 124° C. Thus, it does not require a container that can withstand pressure. It has a flash point of 136° F., which is safely above the temperature required for materials that are to be vaporized in warehouses or dwellings. The relatively high boiling point would appear to be a disadvantage for fumigating purposes, but seems not to be an obstacle. The material is readily vaporized without application of heat. Also, it will pass out of an absorbent carrier at a relatively rapid rate. For example, it can be poured on oblongs of ordinary half-inch *Celotex* at the rate of one-half pound to a piece 8 inches by 12 inches. It will evolve from these oblongs at the rate of 36 per cent in the first hour, 68 per cent in two hours, 95 per cent in four hours, and 99.9 per cent in six hours.

The compound has sufficient odor to give adequate warning of the presence of the gas. It causes a moderate smarting of the eyes but would not be classed as a typical tear gas. The odor disappears rather easily and quickly from fumigated articles. For example, cigarettes which had been fumigated in a tight vault gave no detectable evidence of the gas an hour after aeration.

Prolonged studies have been made as to the effects of the gas on various articles. It has no detectable effect on twenty kinds of furs, nor on many samples of fabrics, including wool, cotton, linen, and rayon, which had been dyed by various processes. It had no effect on 70 samples of wallpapers nor on various samples of wood finishes. It gave no evidence of difficulty with copper, brass, bronze, tin, zinc, lead, nickel, cadmium, silver, or high-grade steel. Ordinary iron in an atmosphere of high humidity was corroded. Dry food stuffs showed no injury nor did grains or cereals. Fresh fruits were definitely injured and so were plants in leaf.

The ability of the gas to penetrate through obstacles was evident in many experiments. Thus, it readily passes through sealed packages of cereals and kills insects within. It penetrates sealed mailing tubes. There is no difficulty in penetrating through flour in sacks.

Using larvae of the yellow mealworm, adults of the confused flour beetle, adults of the rice weevil, and adults of the American roach, 100 per cent kill of these insects, freely exposed to the gas in a tight fumigating valut at 26° C., was attained with the following dosage and time factors:

One-and-one-half pounds per thousand cubic feet, 2 hours; 1 pound, 3 hours; 8 ounces, 4 hours; 4 ounces, 8 hours.

When the same insects were buried in the middle of 100-lb. bags of wheat, placed in the fumigating valut, the dosage and time factors required for 100 per cent kill at 26° C. were as follows:

Three pounds per thousand cubic feet, 4 hours; $2\frac{1}{2}$ pounds, 6 hours; 2 pounds, 8 hours; $1\frac{1}{2}$ pounds, 10 hours; 1 pound, 12 hours.

The gas is apparently relatively safe to human beings. Clinical studies to date seem to indicate that it is no more toxic than the vapor of ortho-dichloro-benzene

at equivalent concentrations. The liquid can be handled as one would handle ortho-dichloro-benzene.

The material is not on general sale but is available in adequate quantities for experimental use by entomologists.—1-7-41.

Hippelates (Eye Gnat) Investigations in the Southeastern States

JOHN T. BIGHAM, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*[1]

Small flies of the genus *Hippelates*[2] are called "eye gnats" on account of their annoying habit of hovering and feeding about the eyes and natural orifices of man and other animals. Their liking for lachrymal and sebaceous secretions, pus, and blood makes them a probable factor in the spread of many diseases, especially infections of the eye and diseases characterized by sores.

The role of *Hippelates pallipes* Loew in the spread of yaws in Jamaica has been described by Kumm (1935), Kumm & Turner (1936), and Saunders *et al.* (1936). Sanders (1940) has shown that *Hippelates* spp. are capable of transmitting bovine mastitis. In the southern states the gnats are closely associated with a seasonal acute conjunctivitis known as "sore eyes," which is especially prevalent among young children. In the Coachella Valley of California, the gnats and sore eyes became such a problem as to demand serious study. Investigations were begun in June 1926 by Herms (1926, 1928), and Herms & Burgess (1930), of the University of California. In 1928 the work was taken up by the Bureau of Entomology, and for several years thereafter studies, chiefly on life history and control measures, were made by Parman (1931), Parman & Burgess (1931), Burgess (1935), and Hall (1932).

These insects were reported in Florida as early as 1894 (Schwarz 1895). In 1932 Bengtson (1933), of the United States Public Health Service, made some bacteriological studies in southern Georgia of the infection known in that region as "gnat sore eyes."

In California the gnats were found to breed chiefly in the freshly cultivated, sandy soil of the irrigated fields. The principal control measures recommended were trapping, sanitation, and certain changes in agricultural practices. Nothing was known concerning the breeding habits of the gnats in the Southeast, and it was thought that in the humid climate of that area the gnats might breed freely in a variety of situations.

SURVEY.—During September and October of 1937 the writer made a survey trip through eastern Texas, Louisiana, the southern parts of Mississippi, Alabama, and Georgia, and the entire state of Florida for the purpose of locating areas of gnat abundance and of ascertaining the prevalence of the so-called gnat sore eyes. This survey was preliminary to detailed studies of gnat breeding by the use of traps and recovery cages. The status of gnats and sore eyes in the various sections was determined chiefly by making numerous local inquiries from school officials, health authorities, and other people.

Since almost all the gnats encountered were of the species *Hippelates pusio* Loew, that is the species referred to throughout this paper except where otherwise stated.

The areas of greatest gnat abundance were found to be the rolling, sandy country of southeastern Alabama and southwestern Georgia, the ridge section of Florida, and several truck-raising sections in Florida. The ridge section of Florida is covered with citrus groves in which the soil is kept disked during most of the year. The gnats are also abundant in the rolling, sandy, farming country of northern Florida, and in certain farming and trucking areas of Mississippi, Louisiana, and Texas. These are also the regions where there are definite yearly outbreaks of the infection gnat sore eyes. In general, it was found that gnats are abundant wherever there is extensive farming or truck raising in

[1] The writer expresses his appreciation to F. C. Bishopp and to D. C. Parman, under whose general direction the work was done.

[2] Diptera: Chloropidae.

sandy or muck soils and are not abundant elsewhere.

The gnats are not abundant in regions of dense, heavy soils, such as the blackbelt of Alabama, with its soils of the Houston series, or the Piedmont section of northern Georgia and South Carolina, with its clayey soils. They are scarce in the flatlands devoted to cattle raising, where there is practically no cultivated land. They are also relatively scarce along the east coast of Florida. This coastal strip has comparatively little cultivated land. There are a good many citrus groves in places, but the groves in this section are not disked. The grass is simply mowed occasionally.

A good many gnats are found around truck fields in the eastern part of Florida, but such fields are usually several miles inland. Practically all the towns and schools, however, are located along the coastal highway, where breezes blow in from the ocean, and it is not to be expected that there would be much complaint about gnats. The marl soil in the vicinity of Miami is probably not favorable for gnat breeding. Along the west coast the gnats are not found at places given over entirely to cattle raising or to the tourist trade, but are very abundant wherever there is much cultivated soil, such as in the trucking areas around Bradenton and Sarasota.

It is a common belief in all the states visited that gnats are found wherever there are oaks.

Wherever gnats are abundant there is also usually a great deal of trouble with sore eyes, although at many places the comment is made that the disease is not nearly so bad as it used to be on account of better medical supervision. Insect sprays are commonly used in school rooms, and sometimes the teachers smear repellents on the childrens' faces or rub castor oil around their eyes. Many of the schoolhouses are screened with 18-mesh wire, and the screens are commonly given credit for keeping the gnats out, although the mesh is obviously not fine enough to keep the gnats from crawling through if they are so disposed. The worst trouble with gnats and sore eyes is experienced in the summer "strawberry schools" wherever such schools are held. During the regular school term the greatest difficulty seems to be experienced in the fall in southern Georgia and northern Florida and in the spring in southern Florida.

In the muck-land trucking section just south of Lake Okeechobee the teachers commonly attribute sore eyes to the irritating properties of muck dust, which blows into the eyes of children working in the fields. This notion seems not to have much medical backing, however.

A county nurse of long experience was very emphatic in her statement that an improvement in the diet of children in poor sections resulted in the disappearance of gnats from school rooms. She contended that this result was not due to greater cleanliness. The diet of the children in these cases had been something bordering on a "pellagra diet." A practicing physician at another place also professed to see a relation between diet and attractiveness to gnats.

In connection with the survey work a good many inquiries were made as to the prevalence of pinkeye in livestock. No relation was discovered between the prevalence of this disease and the abundance of gnats. Most of the cattle found suffering with this disease had been recently imported from western states.

GNAT TRAPPING.—To obtain definite figures on gnat abundance in various localities, a large number of liver-baited traps were operated during the spring and summer of 1938. Traps were located at Dothan, Alabama, Bainbridge and Valdosta, Georgia, and the following places in Florida: Marianna, Tallahassee, Lake City, Cherry Lake, Clara, Gainesville, Hastings, Ocala, Sanford, Ovideo, Zellwood, Orlando, Holopaw, Melbourne, Lake Wales, Fort Pierce, Lake Placid, Sarasota, Arcadia, Punta Gorda, Belle Glade, La Belle, and Fort Myers. Traps had been operated at Orlando, Sanford, Zellwood, Gainesville, Tallahassee, Valdosta, and Fort Pierce during the winter of 1937–38. The traps at Orlando, Sanford, Oviedo, Zellwood, Valdosta, and Fort Pierce were continued up until August 1939. Nearly all these traps were operated by the writer personally and were emptied and rebaited weekly. A few were run by cooperators and were emptied and rebaited every 2 weeks.

The traps used were very similar to the small traps used in the *Hippelates* work in California (Burgess 1935). Each was mounted on a stand covered above with

a cloth canopy and had a half-gallon fruit jar for a light chamber. The bait consisted of 2 ounces of beef liver cut into small pieces, 1 teaspoonful of urea, 1 teaspoonful of table salt, and enough water to make 1 pint. It was prepared several days in advance and kept in a sealed fruit jar until ready for use.

The results of the trapping seemed to confirm previous indications that the abundance of gnats in an area is in direct proportion to the amount of sandy or muck land under active cultivation. All traps that made large catches were located in farming or truck-rising sections, or in regions with disked citrus groves. The largest catch for any one week was made by the trap at Lake Wales, where approximately 96,000 gnats were caught. Lake Wales is surrounded by rolling, sandy hills covered with disked citrus groves. The trap at Sanford located in a celery-raising area caught 77,000 gnats in 1 week, and a trap operated for 1 week in the muck-land celery-raising district east of Sarasota caught 68,000 gnats. On the other hand, traps located at such places as Holopaw or La Belle, in regions devoted to lumbering or cattle raising, never caught more than a few gnats, and often none at all, within a week's time.

The catches of traps located in agricultural areas were sometimes very low during seasons of decreased agricultural activity. The plowing of fields in the vicinity of traps brought about an immediate increase in the numbers of gnats caught. These gnats were apparently attracted by the freshly turned soil. Such occurrences were followed by an increased catch several weeks later, apparently resulting from the breeding which had taken place in the plowed ground. Weather conditions were also responsible for fluctuations in the trap catches, especially during winter months.

Although the great bulk of the gnats caught in the traps were *Hippelates pusio* Loew, there were occasional specimens of *H. nobilis* Loew, *H. plebejus* Loew, *H. proboscideus* Will., *H. pallipes* Loew, and *H. dorsatus* Will.

GNATS RECOVERED IN CAGES.—Field recovery cages were used to locate the breeding places of the gnats. Each cage covered an area of 1 square yard. The sides of the cage consisted of four boards, 1 inch by 12 inches, nailed together at the corners. The top was covered with 8-ounce duck. A hole was cut in one side near the upper edge and a pint fruit jar was screwed into this to form a light chamber. The cages were placed over suspected breeding places and were emptied once a week or oftener by spreading a black oilcloth over the canvas top and beating lightly on the cloth so as to drive the insects out into the fruit jar.

From the results of the recovery-cage work it appears that the great preponderance of *Hippelates pusio* in Florida breed in soil which has been freshly disturbed by plowing, harrowing, digging, or other means. In fact, during the entire course of the work no gnats were recovered from any other source.

Sixty-nine recovery-cage settings were made in situations other than over disturbed soil. These settings may be summarized as follows: Duff in pine woods 4, grass or weed sod 20, rotting vegetation 9, leaf mold in hammock 10, rotting fruit or vegetables 8, moist sand beside lake 2, aquatic vegetation on edge of lake 3, other situations 13. No gnats were recovered from any of the foregoing settings.

Four hundred and thirty nine settings were made over soil which had been worked or disturbed in some way, ordinarily by agricultural practices. These include settings made on experimental plots. An average recovery of 24.2 gnats per setting was obtained, with recoveries ranging from 0 to 517. This average would be much higher had not many of the settings been made in cultivated fields after gnat emergence was complete or partially complete.

In a number of instances settings were made on undisturbed sod within a few feet of settings on plowed ground, with the result that large recoveries were obtained from the plowed ground but none from the sod.

It is not contended that the gnats may not breed to some extent in situations other than disturbed soil, but the results obtained from recovery cages, trapping, and survey all indicate that in the Southeast they are not abundant enough to be of economic importance except where they have cultivated soil for a breeding place. In California, however, gnats occasionally have been found breeding in dead grass and rotten melons.

Although most of the gnats recovered in cages were *Hippelates pusio*, consider-

Table 1.—Recoveries of gnats from cages on experimental plots at Orlando and Zellwood, Fla. Strip at Orlando plowed on afternoon of August 30 and that at Zellwood on morning of September 28, 1938.

Date Cages Were Set	Numbers of Gnats Recovered on Various Weeks from Date of Plowing										
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th
					Orlando						
August 31	0	0	3	3	0	0	—	—	—	—	—
	0	0	5	1	0	0	—	—	—	—	—
September 7	—	0	3	5	0	0	0	—	—	—	—
	—	0	4	3	0	0	0	—	—	—	—
September 13	—	—	5	6	0	0	0	—	—	—	—
	—	—	1	1	0	1	0	—	—	—	—
September 22	—	—	—	0	0	0	0	0	0	—	—
	—	—	—	3	0	0	0	0	0	—	—
September 28	—	—	—	—	0	0	0	0	0	—	—
	—	—	—	—	0	0	0	0	0	—	—
October 4	—	—	—	—	—	0	0	0	0	0	—
	—	—	—	—	—	0	0	0	0	0	—
October 11	—	—	—	—	—	—	0	0	0	0	0
	—	—	—	—	—	—	0	0	0	0	0
					Zellwood						
September 28	0	0	0	11	2	3	0	0	0	—	—
	0	0	0	1	6	0	0	0	0	—	—
October 4	—	0	1	5	2	0	0	0	0	0	—
	—	0	0	7	2	0	0	0	0	0	—
October 10	—	—	0	0	0	0	0	0	0	0	0
	—	—	0	0	1	0	0	0	0	0	0
October 17	—	—	—	3	1	0	0	0	0	0	0
	—	—	—	6	1	2	0	0	0	0	0
October 25	—	—	—	—	2	1	0	2	0	0	0
	—	—	—	—	1	0	0	0	0	0	0

able numbers of *H. plebejus* and a single individual of *H. pallipes* were also obtained from cages placed over cultivated soil. So far as the writer knows, these latter species have not previously been found breeding in nature. It was noticed that *H. plebejus* was sometimes abundant about the places where it was being obtained from recovery cages. It might be mentioned incidentally that *H. plebejus* and *H. nobilis*, which are large species, seem to have mouthparts with enough rasping ability to produce a distinct biting sensation when feeding on one's arms or face.

Experimental Plots.—It seemed desirable to find out how long the gnats continue to breed in soil after it has been turned, to learn something of their seasonal breeding activity, and to determine whether or not the recovery cages produce an artificial condition beneath them that might interfere with the normal development of the larvae.

Two experimental plots were operated during the fall and winter of 1938–39. One was located at Orlando, in a rather low place with sandy soil nearly black with humus, and the other was at Zellwood, on a hill where the soil was deep, loose sand. Strips of ground were plowed at each of these places at approximately monthly intervals, and two recovery cages were set on each strip each week for about 6 weeks, the first cages being set from 4 to 20 hours after the plowing.

The results obtained from single strips at each location are shown in table 1. Recoveries from the other strips were similar.

From the results obtained it appears

that little or no oviposition occurs in plowed land after the first week, and that most of the eggs are laid in the soil within the first few hours after the plowing. Cages set within 24 hours after the plowing usually yielded about as many gnats as those set 2 or 3 weeks later. Cages placed on following weeks did not continue to yield gnats any longer than the first cages, and cages set too late missed the emergence altogether. There seems to have been one definite peak of emergence everywhere on the strips. This peak occurred at a time which would indicate that the eggs had been laid shortly after the plowing.

It also appears that the presence of the cages does not hasten or retard larval development or affect the total number of larvae reaching maturity. Regardless of how long the cages had been in place, the emergence seems to have begun at the same time and to have reached a peak of about the same height at the same time.

With strips plowed later in the season there was a longer interval between the plowing and the peak of emergence, and emergence continued over a longer period. This was to be expected owing to the effect of cooler weather on larval development.

There was some emergence at irregular intervals throughout the winter from strips plowed late in the fall. Several gnats emerged in February and March from strips plowed in November and December. One *Hippelates pusio* was obtained on February 27 from a cage set November 7 on land plowed the same day.

During summer weather the gnats begin to emerge within the third week after the plowing and complete their emergence within a period of about 2 weeks. In several instances they began to emerge within as short a time as 12 days.

There was not much difference in the results from the two localities, Orlando and Zellwood.

On one half of the Orlando plot a much greater quantity of vegetation was turned under by the plowing than on the other half, but equal numbers of cages were set on the two halves on the same dates. Emergence from the two parts was practically the same.

During the spring and summer of 1939 a number of tests involving the use of recovery cages were conducted which are not discussed in detail in this paper but which incidentally confirm the findings presented in the preceding paragraphs. In most cases, however, the recoveries were larger, sometimes more than 500 gnats being obtained from a single cage setting. Since each cage covered 1 square yard of ground, a recovery of 500 gnats per cage would indicate a possible emergence of approximately 2,500,000 gnats per acre.

CONTROL METHODS.—Several tests were conducted during the spring and summer of 1939 looking toward possible control measures. None of these tests was extensive enough to give conclusive results, but intended merely to indicate possibilities for control. Two of the tests will be described briefly.

Most of the truck-raising areas in Florida are equipped for subirrigation, with water supplied by artesian wells. It is a common practice to flood fields and especially seed beds for the control of nematodes and other injurious organisms. To determine the effects of flooding on *Hippelates* breeding, several recovery cages were set on flooded land which had been worked a short time before the flooding. Two of the cages were set in a seed bed where the soil was kept wet to the surface and two others were placed in a bed where the surface of the ground was actually covered with water. Both beds became nearly dry two or three times while the cages were in place. No gnats were recovered.

Two cages were set in a field which had been worked and then flooded for 10 days, then allowed to dry for 2 days before the cages were set. No water was applied after the cages were in place other than rain. No gnats were recovered.

Although none of the cages mentioned above yielded any gnats, all cages on unflooded land in that vicinity yielded gnats, usually in large numbers.

Work done by the Bureau of Entomology and Plant Quarantine in California had indicated that leveling and packing soil after plowing decreases *Hippelates* breeding. To carry out further investigations along this line an experimental plot was prepared at Sanford, Florida. Four strips were laid out. One strip was plowed and left rough; one was plowed and disked; one was plowed, disked, and dragged with a plank drag; and one was plowed, disked, dragged, and rolled with

a 700-to-1,000-pound roller. Eight cages were set on each strip.

The total number of gnats recovered from each strip was as follows: rough plowed 237; disked 390; dragged 575, and rolled 73. The recoveries from individual cages varied so widely that results were not convincing, but there appeared to be a definite reduction in the case of the rolled strip, and increased breeding each time the soil was worked.

The plowing was done with a plow drawn by a tractor and the soil was turned so smoothly that there was little difference in roughness of surface between the rough-plowed strip and the disked strip. About an hour elapsed after the plowing before the disking and dragging were done and several hours more before the strip was rolled. Probably a large part of the oviposition took place within the first hour after the plowing. The reduction in emergence from the rolled strip was probably due to unfavorable conditions for larval development rather than to lessened oviposition. It seems likely that a greater reduction in gnat breeding might be obtained if implements for leveling and packing were attached directly behind a tractor-drawn plow so that the soil would be leveled and packed before there would be opportunity for oviposition.

SUMMARY.—Observations and inquiries made on a survey trip through the Gulf States and Florida indicated that eye gnats are abundant in areas where a large proportion of the land is under cultivation and where the soil is of a sandy or muck type. These findings were later confirmed by the use of baited traps in many localities. The prevalence of sore eyes among school children is closely associated with the abundance of gnats. The use of field recovery cages revealed that practically all eye gnat breeding in the Southeast takes place in freshly cultivated soil. Most oviposition apparently takes place within a few hours after the soil is turned, and there is little or no oviposition after the first few days. During summer weather most of the adult gnats emerge within the third week after the plowing. Tests involving flooding of fields after plowing and leveling and packing soil after plowing indicated possibilities for control along these lines.—1-7-41.

LITERATURE CITED

Bengtson, Ida A. 1933. Seasonal acute conjunctivitis occurring in the Southern States. Pub. Health Repts. [U. S.] **48**(31): 917–26.

Burgess, Robert W. 1935. The eye gnat in the Coachella Valley, California. U. S. Dept. Agr., Bur. Ent. and Pl. Quar. Bul. E-335.

Hall, David G., Jr. 1932. Some studies on the breeding media, development, and stages of the eye gnat *Hippelates pusio* Loew (Diptera: Chloropidae). Amer. Jour. Hyg. **16**(3): 854–64.

Herms, W. B. 1926. Hippelates flies and certain other pests of the Coachella Valley, California. JOUR. ECON. ENT. **19**(5): 692–5

Herms, W. B. 1928. The Coachella Valley (California) Hippelates fly project. JOUR. ECON. ENT. **21**(5): 690–3.

Herms, W. B., and R. W. Burgess. 1930. A description of the immature stages of *Hippelates pusio* Loew and a brief account of its life history. JOUR. ECON. ENT. **23**(3): 600–3.

Kumm, Henry W. 1935. The natural infection of *Hippelates pallipes* Loew with the spirochaetes of yaws. Roy. Soc. Trop. Med. and Hyg. Trans. **29**(3): 265–72.

Kumm, Henry W., and Thomas B. Turner. 1936. The transmission of yaws from man to rabbits by an insect victor, *Hippelates pallipes* Loew. Amer. Jour. Trop. Med. **16**(3): 245–[272]

Parman, D. C. 1931. Construction of the box type trap for eye gnats and blowflies. U. S. Dept. Agr., Bur. Ent. and Pl. Quar. E-299. Mimeographed.

Parman, D. C., and R. W. Burgess. [1931]. Some of the more significant results of recent work on eye gnats (*Hippelates*) and suggestions for control of these gnats and of flies in Coachella Valley, California. U. S. Dept. Agr., Bur. Ent. and Pl. Quar. Bul. E-288.

Sanders, D. A. 1940. *Musca domestica* and Hippelates flies-vectors of bovine mastitis. Science **92** (2387): 286.

Saunders, George M., Henry W. Kumm, and James I. Rerrie. 1936. The relationship of certain environmental factors to the distribution of yaws in Jamaica. Amer. Jour. Hyg. **23**(3): 558–79.

Schwarz, E. A. 1895. The Hippelates plague in Florida. Insect Life **7**(5): 374–9.

SAMUEL HENSHAW

Samuel Henshaw, best known to many entomologists as the author of the valuable check-list of the Coleoptera, died in Cambridge, Massachusetts on February 5, 1941. He was born on January 29, 1852.

While Henshaw was a biologist of broad interests he was considered by entomologists as an entomologist and his work in the field will remain as a monument to his memory.

Hibernating Codling Moth Larvae[1]

EDWIN GOULD, *W. Va. Agricultural Experiment Station*, and GEO. H. GEISSLER,
U. S. Bureau of Entomology and Plant Quarantine

As is well known, codling moth control has become increasingly difficult during the last several years and, in heavily infested districts, the insect has not been satisfactorily controlled by spraying.

As a result of this condition a project, cooperative between the West Virginia Agricultural Experiment Station and the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture, was inaugurated for the study of certain possible practices which might supplement or replace the spray program. The project has been called the "Biological-Mechanical Control Project" and the work is in progress in an 18-acre orchard planted in Frankstown Gravelly Silt Loam soil and located near Martinsburg, W. Va. In the course of the work in this project the data presented ahd discussed in this paper have been secured.

In consideration of mechanical and other means for controlling the codling moth the importance of accurate and detailed knowledge of the hibernating habits of the insect was apparent. While it is a matter of common knowledge that the larvae find hibernating quarters in a great variety of situations, such general knowledge was not considered sufficient for the purpose of the study in progress. Consequently, during December, 1939, a detailed study of the distribution of the hibernating larvae in the Biological-Mechanical Control orchard was made. While the information thus secured may not apply exactly to orchards which have not been subjected to the same treatment, much of it doubtless parallels closely the conditions existing in commercial orchards.

METHODS AND RESULTS.—Six trees were selected for the examination. Four years' band records were available for five of these trees. The location of the trees and the varieties used are shown in figure 1. Each tree was examined in minute detail. All trash and debris beneath the trees and the soil to a depth of approximately three inches was carefully examined. The soil was sifted through a series of screens, the last of which was fine enough so that a normal full grown larva could not pass through. The location of each recovered larvae was noted. The height from the ground, the distance from

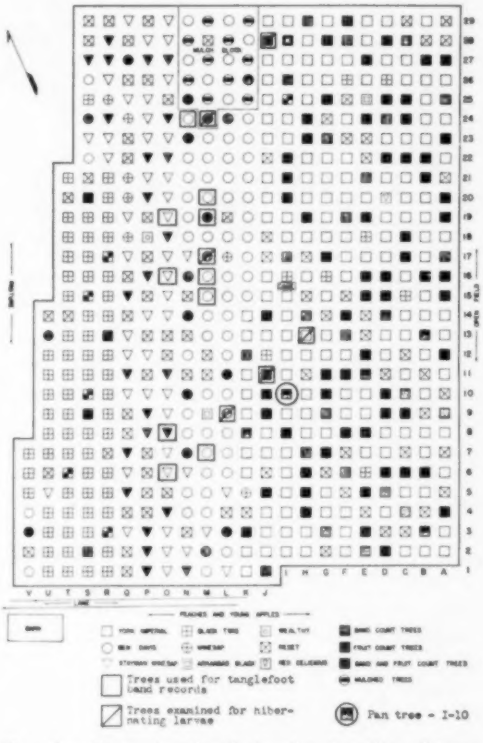


FIG. 1.—Map of orchard showing location of trees included in the study.

the trunk, circumference of limb at point of location, direction and type of cover were noted for each larva recovered. It required approximately 150 hours time to examine each tree.

The detailed results from the examinations are given in table 1. No larvae were found in either soil or the debris beneath any of the trees examined.[2] The failure to find larvae in the soil was probably due largely to the type of soil and soil cover. The soil was gravelly and compact and

[1] Published with the approval of the Director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 264.

[2] The examination of the soil and debris from the six trees resulted in the recovery of 151 larvae, all of which were identified by Carl Heinrich of the Division of Insect Identification, as *Holcocera maligemmella*, Mtfd. The insect was quite abundant in fallen fruits throughout the orchard.

Table 1.—Location of hibernating codling moth larvae,—December, 1939.

Measurement*	Tree H-13			Tree J-11			Tree J-28			Tree L-9			Tree M-17			Tree M-24			Total Larvae		
	No. Larv. Rec.			No. Larv. Rec.			No. Larv. Rec.			No. Larv. Rec.			No. Larv. Rec.			No. Larv. Rec.			No. Larv. Rec.		
	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.	Ht.	Dist.	Circ.
0	—	3	—	—	4	—	—	1	—	—	6	—	1	7	—	—	—	—	1	21	—
1	—	—	—	3	6	3	1	5	2	2	4	3	2	—	2	—	—	2	8	15	12
2	2	1	5	—	—	5	—	—	2	4	3	3	1	1	3	—	—	1	7	5	19
3	1	1	4	4	—	5	6	1	—	4	1	3	—	10	1	3	3	15	18	16	28
4	5	1	—	8	—	5	6	1	4	6	5	3	5	—	2	4	2	4	34	9	18
5	3	5	—	4	1	2	2	6	—	4	6	—	10	1	3	2	—	2	25	19	7
6	—	4	2	—	—	—	4	3	5	4	—	1	5	2	—	—	9	5	13	18	13
7	1	—	1	3	1	—	—	2	—	3	2	1	1	25	4	4	—	5	12	30	11
8	7	3	12	7	5	6	1	1	—	4	1	3	—	2	—	19	4	—	38	16	21
9	—	2	6	—	8	1	1	—	—	2	5	2	—	3	1	1	—	—	4	18	10
10	—	10	—	—	2	3	—	1	3	—	—	—	26	4	7	1	2	1	27	19	14
11	6	12	6	2	4	—	—	1	5	—	—	—	3	—	1	1	2	1	12	19	13
12	3	6	—	—	1	—	—	—	—	—	4	—	1	2	—	—	14	—	4	27	—
13	4	—	—	—	1	—	—	—	—	—	—	—	—	—	25	—	1	—	4	2	25
14	4	2	5	1	3	1	1	—	—	2	1	4	—	1	—	1	—	1	9	7	11
15	8	—	4	—	—	—	—	—	—	3	—	—	—	2	2	1	—	—	12	2	6
16	5	—	1	2	2	—	—	—	—	—	—	4	4	—	1	—	—	—	11	1	6
17	—	1	—	2	—	—	—	—	—	—	—	—	1	—	—	—	—	—	3	1	—
18	1	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	1	—	2
19	—	—	—	1	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	1
20	1	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—	1
21	—	—	2	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	5
22–34	—	—	2	—	—	3	—	—	1	—	—	—	—	—	3	—	—	—	—	—	9
38–42	—	—	1	—	—	3	—	—	—	—	—	6	—	—	3	—	—	—	—	—	13
Total Larvae	51	51	51	37	37	37	22	22	22	38	38	38	60	60	60	37	37	37	245	245	245

* The height of larval location from the ground and distance of location from trunk are given in feet while the circumference at point of location is given in inches.

did not afford readily accessible hibernating quarters for the larvae. There was practically no organic matter in the soil and comparatively little cover beneath the trees since the growth of vegetation had been kept at a minimum. Most of the debris consisted of leaves and fallen fruits.

SINGLE TREE STUDIES.—During the season of 1939 a detailed study was made to determine the actual population of codling moth larvae in a given tree and as much as possible of the normal behavior of this population. A York tree (1–10) was selected for this study. The results obtained indicated that approximately half of the worms of a given population drop to the ground, either free or in fruits. It would, therefore, be expected that some of those individuals would hibernate in any suitable cover which they could find. In addition to the examination of the six trees a large quantity of trash and debris of all types was gathered at random from all parts of the orchard and found to contain only two codling moth larvae. This would indicate that a very small percentage of the overwintering larvae hibernate in the debris on the ground. In Illinois, Chandler (1926) reported finding 30 per cent of the hibernating larvae in the soil just below the surface. Of those found on the ground between the trees he noted that there were eight times as many in artificial situations as in natural cover, pieces of bark being the only types of cover in which the larvae on the ground were found. In the same region Flint & Chandler (1934) found that 80 per cent of the overwintering larvae were in tree bands, 13 per cent on the tree and 7 per cent on the ground. In Australia, Allen (1927) found 38 per cent of the overwintering larvae beneath the soil immediately adjacent to the trunk of the trees. In New Jersey, Headlee (1929a, 1929b) found in a cultivated orchard that 91 per cent of the overwintering generation emerged from the trunk and large branches in the region covered by rough bark, 9 per cent from the twigs and branches above the rough bark and none from the ground beneath the tree.

Gandinger *et al.* (1940) at Wenatchee, Washington, examined four trees and found from 81.9 to 98.4 per cent of the overwintering larvae on the tree, 0.9 to 1.6 per cent in the soil, none to 2.9 per cent in the cover crop and none to 13.8 per cent in debris on the ground. No larvae were found in the soil more than 24 inches from the tree. Larvae found in the soil more than 8 inches from the tree were not more than 3 inches below the surface. No larvae were found in the cover crop under three of the trees. Only 1.2 per cent were found in the soil and all but one of these were within 3 inches of the surface.

Headlee (1930) found that 63 per cent

of the adults emerged from the trunk and rough bark portion, 37 per cent from the top and none from the ground. Steiner (1929) reported that most of the overwintering larvae cocoon on the trunk of the tree yet 20 per cent or more might be found at other places on the tree and on coarse debris or vegetation on the ground. Worthley (1932) found 1.5 per cent of the larvae on the ground, 1.66 per cent on the tree and 96.84 per cent in bands. Chugunin (1929) reported 51.8 per cent of the cocoons were found on the trunk within 4 inches of the ground. He also found 74.7 per cent of them on the south side of the trees.

Under eastern conditions the ground population can be practically eliminated keeping the growth of vegetation and debris beneath the trees at a minimum. The soil should be kept fairly smooth and firm in order to avoid forming locations suitable for the larvae to spin their cocoons. In this section even under normal orchard conditions there is but little successful emergence from the ground or in the soil even where mulching is practiced. It is difficult to find successful hibernation even in such favorable mulch as corn fodder.

Examination of fallen fruits revealed no codling moth larvae. In addition to the fruits under the trees examined, 1,000 apples were gathered at random from all parts of the orchard and examined for larval content but were found to contain no codling moth. These results indicate that practically all of the young larvae in the fallen fruits either emerge or are destroyed. Since no full grown larvae were found on, in or near the ground under any of the six trees examined, it is apparent that those individuals which drop to the ground and do not ascend the trees and find hibernating quarters, are destroyed by predators and other natural factors.

There was no apparent significance in the location of the recovered larvae. The results indicate that larvae tend to find hibernating quarters purely by chance. They apparently have no instinct for special locations or types of cover but seem to wander aimlessly until they accidentally find a suitable location. It is interesting to note the large number of larvae found in the ends of fruit spurs and small twigs. Of the 245 larvae recovered from the six trees examined 77 (31.4 per cent) were on limbs and twigs which were less four inches in circumference at point of larval location. More than half of the larvae recovered were on limbs which were less than eight inches in circumference at point of larval location. As the branches became larger the number of larvae recovered decreased. There were only 14 (5.7 per cent) on the trunks and 18 (7.4 per cent) on the main scaffold branches. The remaining 213 (86.9 per cent) were recovered from smaller branches and twigs. No larvae were found on the trunks of any of the trees within 11 inches of the ground. This was probably due largely to the thorough annual scraping of the trees for the past four years. Practically all rough bark and obviously satisfactory hibernating quarters had been removed as shown in figure 2. Only the trunks and main scaffold branches were scraped. The bands on the trunks and main scaffold branches also contributed to the low recovery from these areas.

FIG. 2.—Condition of trunk and main branches on one of the trees included in the study. Note also the lack of soil cover.

Table 2.—Direction of location of hibernating larvae.

	H-13	J-11	J-28	L-9	M-17	M-24	TOTAL
North	27	12	6	9	9	6	69
East	14	7	6	1	33	2	63
South	8	15	6	15	11	7	62
West	2	3	4	13	7	22	51

The data given in table 2 indicate that

there was no apparent significance in the direction of larval location on the trees. This was further indication that availability of suitable cover is the one important factor in determining the location of overwintering larvae.

FIG. 3.—An area on tree M-17 where a limb had splintered off leaving cover ideal for hibernating codling moth larvae. Twenty-five larvae or 41.7 per cent of the entire overwintering population of the tree were recovered from this area.

Since the trees examined had been thoroughly scraped the most abundant remaining suitable cover was in pruning wounds and knot holes (Table 3). It was

Table 3.—Type of location of larvae.

	Tree H-13	Tree J-11	Tree J-28	Tree L-9	Tree M-17	Tree M-24	Total
Pruning Wound	38	22	2	8	9	14	93
Knot Hole	1	7	15	17	16	3	59
End of Small Twig	—	—	3	7	4	3	17
Broken Limb	2	7	1	4	28	16	58
Under Bark	10	1	1	2	3	1	18

in this type of cover that a large percentage of the recovered larvae were found. Of the 245 larvae recovered from the six trees 152 (62.0 per cent) were found in pruning wounds and knot holes, 17 (6.9 per cent) in the end of fruit spurs and small twigs, 58 (23.7 per cent) in areas where limbs had broken off and 18 (7.4 per cent) beneath small pieces of bark. There was an average recovery of 41 larvae per tree. The large recovery from tree M-17 was accounted for by two areas where limbs had splintered off leaving cover ideal for larvae to hibernate. Twenty-five larvae were recovered from one of these areas (Fig. 3) on the east side of the central leader where a large limb had splintered off. Seven larvae were recovered from another splintered area on the same tree. The 32 larvae recovered from these two small areas represented 53 per cent of the entire overwintering population recovered from the tree. Had these two favorable locations been removed most of these larvae would probably have been collected in bands and destroyed. This further emphasizes the importance of thorough removal of all available hibernating quarters in order to increase the effectiveness of bands. Twelve larvae were recovered from a similar type of location on tree M-24 and eight from one on tree H-13. It is quite obvious that an overwintering population could be reduced greatly by removing a few such favorable hibernating places.

In order properly to interpret the results it is necessary to use the results from the population-behavior study made in the same orchard during the current season. These results indicate that on well scraped trees approximately 27 per cent of the larvae of a given population are collected in trunk and scaffold limb bands, 40 per cent are destroyed by predators and other natural factors and 3 per cent remain in the harvested fruits. This gives a total of approximately 70 per cent of the total seasonal population which is accounted for. The tree examination records show only 3.2 per cent of the total population overwintering on the trees, leaving approximately 25 per cent of the population unaccounted for. The fallen fruits were gathered twice during the season and removed from the orchard thus eliminating at least a few larvae from the orchard which would normally have returned to the trees. There was also some emergence on the trees during the season which would have accounted for quite a portion of the 25 per cent unaccounted for. Undoubtedly most of the remainder were destroyed by predators.

Table 4.—Summary of results for six trees examined.

	TREE H-13	TREE J-11	TREE J-28	TREE L-9	TREE M-17	TREE M-24	TOTAL	AVE.
Yield in Bushels	32	29.75	17.25	11	14.5	11.5	116	19.33
Total Number Fruits[1]	7552	7021	4071	2596	3422	2714	27376	4562
Number Injured Fruits[2]	4663	4335	2513	1603	2113	1676	16903	2817
Number Worm Injuries[3]	8534	7934	4600	2933	3867	3067	30935	5155
Total Number Larvae (Est.)[4]	2134	1984	1150	733	967	767	7735	1289
Number Larvae on Tree (Est.)[5]	1027	955	553	353	465	369	3722	620
Number of Larvae Dropped to Ground (Est.)[6]	1042	969	562	358	472	375	3778	630
Number Larvae Remained in Harvest Fruit (Est.)[7]	65	60	35	22	30	23	235	39
Ground Larvae Destroyed Predators (Est.)[8]	831	773	448	286	377	299	3014	502
Ground Larvae Returned to Tree (Est.)[9]	211	196	114	72	95	76	764	127
Total Tree Population (Est.)	1238	1151	667	425	560	445	4486	748
Number Larvae Caught in Bands	610*	505	255	271	301	269	2211	369
Number Larvae Escaped Bands on Tree (Est.)	628	646	412	154	259	176	2275	379
Emergence of Tree Larvae (Est.)[10]	314	323	206	77	129	88	1137	190
Estimated Tree Population (Est.)[10]	314	323	206	77	129	88	1137	190
Larvae Recovered from Tree	51	37	22	38	60	37	245	41
Larvae Unaccounted for	263	286	184	39	69	51	892	149
Per cent of Larvae Unaccounted for	12.3	14.4	16.0	5.3	7.1	6.6	—	11.5
Total Larvae Recovered	661	542	277	309	361	306	2456	409

[1] Average fruits per bushel—236.
[2] Average per cent injured—61.7.
[3] Average worm injuries per 100 fruits—113.
[4] Average of one larva for each 4 worm injuries.
[5] Per cent of total population which remained on tree—48.1.
[6] Per cent of total population which dropped to ground—48.8.
[7] Per cent of total population which remained in harvest fruit—3.1.
[8] Percentage of ground larvae destroyed by predators—79.8.
[9] Percentage of ground larvae returned to tree—20.2.
* Estimated on basis of other five trees.
[10] Approximately half of the larvae which escaped the bands on the trees emerge during the season and the remainder hibernate.

The population behavior study made on tree I-10 showed that 32 larvae were recovered from the tree during the season, five of these were recovered before August 1 and would probably have pupated during the current season. In all, 21 pupal cases were recovered. This gave a total of 26 larvae which escaped the bands and either pupated or should have pupated on the tree during the season. A total of 53 larvae escaped the bands. Twenty-six of those which escaped the bands pupated during the current season. This means that approximately as many moths emerged from the trees examined as there were overwintering larvae remaining at time of examination. Table 4 gives a detailed summary of the results for the six trees examined and table 5 gives some previous records for the same trees.

The data given in table 4 show the total seasonal worm population for the six trees examined and indicate that 28.6 per cent of all the larvae were collected in bands, 3.1 per cent remained in the harvested fruits, 39.0 per cent were destroyed by predators and other natural factors, 14.7 per cent escaped the bands and emerged during the season, 11.5 per cent were unaccounted for and only 3.1 per cent over-

Table 5.—Previous records for trees examined.

	1936		1937		1938		1939		AVERAGE	
TREE	Yield in Bu.	Larvae in Bands	Yield in Bu.	Larvae in Bands	Yield in Bu.	Larvae in Bands	Yield in Bu.	Larvae in Bands	Yield in Bu.	Larvae in Bands
H-13	20¾	—	18½	—	6¼	—	32	—	19⅓	—
J-11	4½	180	22¼	639	¼	15	29¾	505	14¼	335
J-28	4	117	12¼	546	1	94	17¼	255	8⅔	253
L-9	5½	241	2¼	208	5	505	11	271	6	306
M-17	3½	203	9	274	6¾	593	14½	301	8½	343
M-24	19½	341	8	167	20¾	873	11½	269	14¾	413

wintered on the trees. Probably most of the larvae unaccounted for were destroyed by predators and other natural agencies. Disregarding the larvae destroyed by predators and those remaining in the harvested fruit it will be noted that bands caught over 60 per cent of those larvae which would normally have survived.

There are a number of reasons why the percentage of overwintering larvae was so small. It is based on the total worm population for the entire season instead of on just the overwintering generation. The results were taken in a lightly sprayed orchard where natural control factors were little disturbed. The trees examined had been scraped thoroughly during previous years to remove as much as possible of the natural suitable cover. There was an average recovery of 41 larvae per tree for the six trees examined. It was significant to note, however, that this small number of overwintering larvae per tree resulted in a first brood infestation of 36.4 per cent the following season (1940).

SUMMARY.—The importance of the various locations of hibernating codling moth larvae depends largely on the ease with which the larvae can find satisfactory places to cocoon. The location and abundance of overwintering larvae is determined largely by the abundance of suitable cover. There is no apparent significance in the location of the recovered larvae. Apparently the larvae find hibernating quarters purely by chance and have no instinct for special locations or types of cover.

No larvae were recovered from either the soil or the debris beneath any of the trees examined.

Approximately 28 per cent of the total worm population was collected on trunk and main scaffold limb bands, 3 per cent remained in the harvested fruit, 39 per cent was destroyed by predators and other natural factors, 15 per cent escaped destruction and emerged, 12 per cent was unaccounted for and only 3 per cent overwintered on the trees. More than 60 per cent of all surviving larvae were caught in trunk and scaffold limb bands.

Approximately 31 per cent of the overwintering larvae were recovered from twigs and limbs less than four inches in circumference at point of larval location. Only 5.7 per cent were recovered from the trunks and 7.4 per cent from the main scaffold limbs. Almost half of the recovered larvae were concentrated in a few very favorable locations. An overwintering population of 41 larvae per tree gave a first brood infestation of 36.4 per cent the following season.—12-11-40.

LITERATURE CITED

Allen, S. L. 1927. Agr. Gaz., N.W.S., **38**(11): 861.
Chandler, S. C. 1928. Codling Moth Hibernation Studies, JOUR. ECON. ENT. **21**: 315–8.
Chugunin, (Ya). 1929. Data on the Ecology of *Cydia pomonella*, L. (In Russian). Sad i Ogorod, 1929, No. 10: 25–31, Moscow (Rec'd. 1931).
Dozier, H. L. 1926. Ann. Rept. of the Director of Del. Agr. Expt. Sta., Del. Bul. **147**: 17–9.
Flint, W. P., and S. C. Chandler. 1934. Trans. Ill. Hort. Soc. **67**: 491–505.
Gnadinger, C. B., J. B. Moore, and R. W. Coulter. 1940. Experiments with pyrethrum for the control of codling moth (*Carpocapsa pomonella* L.) JOUR. ECON. ENT. **33**(1): 143–53.
Headlee, T. J. 1929a. Rep't. Dept. of Ent., N. J. Agr. Expt. Sta. for 1928. Also JOUR. ECON. ENT. **22**: 89–97.
Headlee, T. J. 1929b. Practical control of codling moth in a heavily infested district. JOUR. ECON. ENT. **22**(1): 89–97.
Headlee, T. J. 1930. N. J. Exp. Sta. 43rd Ann. Rept., **51**: 142–4.
Mackie, D. B., and W. B. Carter. 1939. Supplementary control of codling moth, Bul. Calif. Dept. of Agr. **28**(6): 378–86.
Steiner, L. F. 1929. Miscellaneous Codling Moth Studies, JOUR. ECON. ENT. **22**: 648–54.
Worthley, H. N. 1932. Chemically treated codling moth bands in Pennsylvania, JOUR. ECON. ENT. **25**: 1133–42.

SEVENTH PACIFIC SCIENCE CONGRESS

The Seventh Pacific Science Congress is scheduled to be held in Manila in November, 1943, under the auspices of the National Research Council of the Philippines. Problems related to entomology of the Pacific will be given an important place in the Congress under the following main subdivisions: (a) insects in the Pacific; (b) biological control of insects in the Pacific; (c) plant quarantine.

Opportunities to visit parts of Luzon and the southern islands of the archipelago will be afforded through the various excursions planned in connection with the Congress. Tropical virgin forests within easy access from Manila provide excellent collecting grounds. Entomologists who are intending to attend this Congress are invited to communicate with Dean L. B. Uichanco, Secretary, Section of Economic Entomology, Seventh Pacific Science Congress, Agricultural College, Laguna, Philippines.

Observations on the Egg and Newly Hatched Larva of the Corn Ear Worm on Corn Silk

GEO. W. BARBER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In research on the insecticidal control of the corn ear worm, *Heliothis armigera* (Hbn.), attacking ear corn one of the first questions that presented itself was, Where do the newly hatched larvae begin to feed? Except for records of the larvae eating eggshell (Quaintance & Brues 1905) no answer appears in the literature.

During the period February to April 1936, while working in Belle Glade and in Homestead, Fla., the writer had an opportunity to study this problem. Individual larvae were observed under a binocular microscope continuously from the time they began to bite through the eggshell until they had migrated and had become lost to view among the closely massed strands of silk at the tips of the ears. About 4 dozen larvae were observed in this way, and complete histories of the behavior of 41 were recorded. The following account is the result of these observations, together with much related data.

POSITION OF THE EGG ON CORN SILK.—Corn ears vary greatly in the abundance and length of the silk strands, and ear worm eggs may be deposited upon the silks anywhere from the point where they emerge from the husk to their tips, besides being laid less often upon the husks or on other plant parts.

To determine the usual position of eggs laid on the silks of Snowflake corn, the distance from the tip of the husk to the location of 500 eggs was measured. It was found that eggs occurred from 0 to 162 millimeters from the tip of the husk in normal ears, the average distance being 52.3 millimeters. Of the total number of eggs observed, 93.2 per cent were found to be from 0 to 100 millimeters from the husk tip and 68.6 per cent between 20 and 70 millimeters from the tip. These figures give a general idea of the distance the larvae must migrate after hatching to reach the tip of the husks in this variety of corn.

VARIATION IN SIZE AND IN SHAPE OF EGGS.—Observations on the activities of newly hatched larvae showed that individuals behaved differently. This difference in behavior seemed to be dependent in part upon the size of the eggs from which larvae hatched.

In a series of 250 eggs collected at random from corn silks in cornfields considerable variation was found, not only

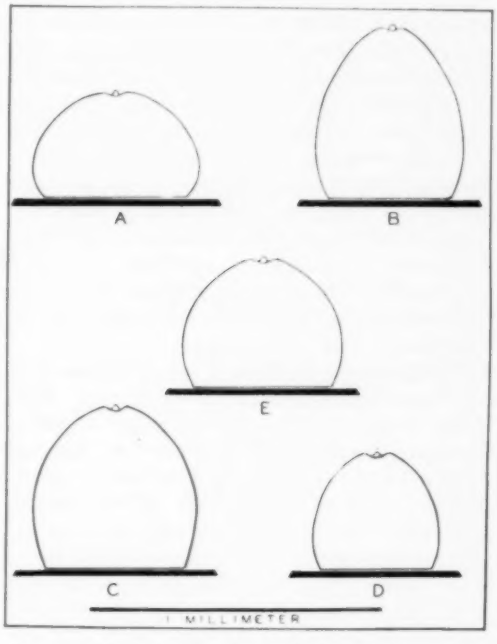


FIG. 1.—Variation in size and shape of corn ear worm eggs: A, B, C, and D, eggs of extreme dimensions, and E, egg of average dimensions.

in size but in shape. In diameter the eggs ranged from 0.423 to 0.585 millimeter and in height from 0.358 to 0.585 millimeter. The ratio of the greatest to the least diameter was 1 to 0.72, whereas for height this ratio was 1 to 0.60.

The average diameter was 0.536 millimeter, the average height 0.455 millimeter, and the average ratio of diameter to height 1 to 0.85. The extreme ratios of diameter to height were 1 to 0.64 and 1 to 1.2. Eggs of extreme dimensions are compared with an egg of average dimensions in figure 1.

The largest egg was 0.552 millimeter in diameter and 0.552 millimeter in height and the smallest egg 0.455 millimeter in diameter and 0.406 millimeter in height. The volume of the smallest egg, therefore,

was somewhat more than half that of the largest. Among the extreme variations of height and diameter there occurred 67 different combinations, the largest number of eggs of one set being 20.

It seemed that larvae hatching from larger eggs, having been provided with a greater amount of nourishment before hatching, were not eager to begin feeding immediately after hatching, whereas the reverse seemed to be true of the less nourished larvae hatching from smaller eggs. This factor, therefore, was possibly a partial explanation of the observed differences in habits of newly hatched larvae.

APPEARANCE OF THE EGG BEFORE HATCHING.—When first deposited the egg is cream colored. The developing embryo is first observed as a coiled brown line but darkens during the period immediately before hatching and is discernible through the shell. The shell is parchmentlike and is capable of being bent without breaking even after hatching. It is white and translucent after hatching.

While in the ovary the egg is cylindrical and somewhat longer than broad. The sides are nearly parallel, but slightly bowed outward, and the base and tip are similarly rounded and flattened where pressed against other eggs. When laying egg, the moth thrusts the tip of her abdomen against a corn silk and forces the egg against the silk. At this time the egg seems to be plastic, and that portion which is forced against a surface by the moth conforms to that surface. The nature of the surface against which the egg is pressed and the degree of force used by the moth seem to determine, in part at least, its resulting shape. If deposited on a perfectly flat surface, the egg is likely to be broader than high. On the other hand, if laid on a narrow surface, the shape is likely to be the reverse. Usually eggs are laid on flat or nearly flat surfaces.

Before deposition the base of the egg seems to be unsculptured, but upon oviposition it takes and retains imprints of the surface on which it is placed. The remainder of the egg bears from 24 to 30, or an average of 27, ridges, which run vertically from the base to near the apex. Usually the alternating ridges do not extend as far upward as the others. The apex is indented and from its center arises a sculptured nipple. The grooves between the ridges bear minute transverse ribs.

The shell resembles embossed parchment and does not appear to be greatly thickened at any point. The structure of the shell seemingly determines certain habits of the larva when it begins to gnaw its way out of the egg.

HATCHING.—Immediately before hatching the larva lies coiled within the egg, completely filling it. If the egg is of the usual shape, with the apex directed upward and centrally located with respect to the base, the central dorsal surface of the larval head rests against the tip of the egg, with the mandibles about equally distant from the tip on each side and about one-fourth the distance from tip to base.

When ready to emerge the larva begins to bite without altering its position. It may continue to bite ineffectively for some time, but eventually, after becoming more vigorous or slightly adjusting its position, it succeeds in biting through a groove of the shell. Continued biting soon enables it to penetrate an adjoining groove. These two openings enable the larva to thrust a mandible through each and bite through the ridge lying between the two punctured grooves. After slightly adjusting its position the larva continues to cut through grooves and ridges in the manner described until a slit has been cut across the egg transversely through some six or more ridges. After further adjustment the larva eats the shell along the lower edge of the slit and then on either side of the slit until a roughly circular area, similar in diameter to its head, has been devoured. The larva now has prepared a way through which it crawls from the egg.

The period from the first cutting of the eggshell to the thrusting of the head through the emergence hole ranged from 6 to 42 minutes for 19 individuals, or an average of 19.5 minutes. The period from the first thrusting forth of the head to complete emergence ranged from 2 to 24 minutes for 31 individuals, or an average of 6.5 minutes.

ENVIRONMENT OF THE LARVA.—For egg laying the ear worm moth prefers fresh corn silk to any other part of the plant. This usual environment of the newly hatched larva is described with particular reference to the varieties Snowflake and Tuxpan, which are commonly grown in southern Florida during the winter.

Counts showed that an average ear of

either of these varieties has about 800 silks, which extend about 100 millimeters beyond the husk tip. Each exposed silk strand bears on an average 9.1 setae per millimeter. Hence, under average conditions, each ear has a total of about 80,000 millimeters of exposed silk, bearing some 728,000 setae. A silk strand of either of these varieties is approximately as thick as a newly hatched larva and twice as wide, and a seta is often twice as long as the larval diameter. Thus it seems evident that the larva finds itself in a veritable forest of silk and setae, through which it must find its way to the ear.

As soon as pollination occurs, the silk strands begin to wilt and probably become progressively less attractive as food for the larvae. Usually the larvae begin to hatch after the silk strands have begun to wilt. The wilted exterior silk appears to be tougher and more difficult to bite into than unwilted interior silk.

The setae are much longer and more abundant on that portion of the silk outside the husk, especially toward the ends of the strands, than on the portion covered by the husk. On the latter they are often abortive. A count showed that in the variety Snowflake the terminal centimeter of a silk strand, which was forked for the last 8 millimeters, bore 178 setae. Fifteen counts at three intervals between the tip of the husk and the extremity of the silk showed on an average 91 setae per centimeter, whereas ten similar counts on interior silk at two intervals between the kernels and the tip of the husk showed on an average 77.5 setae per centimeter.

HABITS IMMEDIATELY AFTER HATCHING.—The habits of the larvae from the time they complete emergence from the eggs to the time they reach the tip of the ear may be divided into three periods, namely, eating, resting, and migrating.

As soon as the larva thrusts its head through the opening it has eaten in the eggshell, it begins to lay down silk on the shell, on the strand of corn silk bearing the egg, or on any adjoining surface within reach. This silk, which is deposited by alternate right and left thrusts of the head, provides a firm foothold, enabling the larva to catch hold with its tarsi and exert the pull necessary to remove its coiled abdomen from the egg. As the larva gradually pulls itself from the egg it continuously lays silk in a lengthening web on the surface to which the egg is attached, usually a strand of corn silk, until it has entirely emerged.

On completing emergence the larva usually is extended full length upon the corn silk, with its head farthest from the egg. The webbing of silk spun during emergence provides it with a firm foothold on the plant, which may be swaying in the wind, while feeding and resting. It continues to spin silk on the surface wherever it walks until it is hidden from view within the ear, although less abundantly during migration. Without the silken support the true legs slide over the corn silk without catching, whereas both the tarsi of the true legs and the crotchets of the prolegs hold to the silken web securely.

After completing emergence, the larva reverses its position on the silken web. This reversal brings the head into contact with the eggshell, and this shell, on which the larva had already fed during hatching, usually is its first food. Of 41 complete histories of emergence habits, newly hatched larvae ate upon the shell of their eggs after emergence in 70.7 per cent of the instances. Some of them merely nibbled at the shell, consuming very little of it, whereas others devoured a large part of it.

To obtain further information on the shell-eating habits of larvae, the eggs from which 555 larvae had emerged were collected, and estimates on the extent of shell eating were made. These eggs had hatched on silks in all stages from fresh and moist to brown and dry. These were the conditions under which eggs occurred on corn ears in the field. The examination showed that 63.1 per cent of the larvae had eaten the shell and that 36.9 per cent had not, except to make an emergence hole. Further examination showed that 1.1 per cent of the larvae had eaten only a trace of the shell, 3.4 per cent had eaten up to one-fifth of the shell, 10.6 per cent from one-fifth to two-fifths, 13.2 per cent from two-fifths to three-fifths, 22.0 per cent from three-fifths to four-fifths, and 12.8 per cent from four-fifths to all of the shell. In general, larvae that hatched on dry silks ate the shell more often than those that hatched on fresh silks, probably because the usual alternate food was not in a condition to attract them.

Some of the observed larvae which did not eat the eggshells ate setae of the corn silk, occasionally devouring all the setae

along the corn silk adjoining and on each side of their silken foothold. Many of the larvae that ate eggshell also ate a few setae. Of 41 larvae 10 ate only eggshell, 19 ate shell and setae, and 12 ate setae alone. All larvae did some feeding before reaching the tip of the ear. Thirty-one of the 41 larvae fed on setae during some period of their activities between the time they emerged and the time they reached the tip of the ear. Twenty-three of 40 larvae ate setae during the active period immediately following hatching, 18 of 20 larvae ate setae intermittently during their resting period, and 9 of 19 larvae ate setae during their migration to the ear tip. Most of the larvae ate setae during the first two periods and some of them during all three periods. The seta-eating habit appeared, therefore, to be well developed. Of the 41 larvae observed 19 tried to bite into the corn silk in the vicinity of their silken footholds, but only 4 succeeded. This may have been because the wilted silk was too tough by the time the larvae hatched or because their mandibles were not hardened sufficiently to bite into the silk but were hardened enough to enable them to eat the eggshell and more tender setae.

In eating setae the larva usually eats from the tip downward, and one larva was observed to feed in this way when only its head had emerged from the egg. Larvae sometimes sever setae at their bases and eat them while held in their mouthparts.

In eating the eggshell the larva feeds in the same manner as when feeding on the edge of a leaf. It usually straddles the edge of the shell and holds on with its true legs. It reaches upward for a first bite, eats downward in an arc to a point just above the legs and then reaches upward to begin eating another section of shell, continuing in this way and occasionally adjusting its position.

Shell feeding is much more continuous than seta feeding. Once a larva has begun to eat shell, it is likely to feed steadily. Some larvae interrupt their feeding with short rests, especially those that eat only setae. Others interrupt feeding with short exploratory excursions, but they usually do not travel more than their own length from the silken foothold. Such larvae eat a few setae or try to bite into the corn silk, but return from time to time to the shell for further feeding. For 26 shell-eating larvae observed the time occupied in such feeding ranged from 3 to 45 minutes, the average being 21.2.

After satisfying their immediate urge to eat, most larvae take up a resting position, in which they pass the second phase of their postemergence activity.

RESTING PERIOD.—The larvae usually pass the resting period on the silken footholds. When exposed to bright sunlight, however, some larvae pass this stage on the undersides of silk strands, usually near the egg. One individual was observed to wander some distance from the egg before resting.

During the rest period the larva usually remains motionless except for brief periods during which it eats a bit of shell or a few setae or explores in the vicinity of its resting position. In this position the larva clings to the silken foothold with its prolegs, the anterior portion of the body being slightly raised from the surface, with the true legs gathered together, the head slightly bent downward, and the thorax humped.

Of 40 larvae observed during this period 26 passed through a distinct resting period, 10 rested intermittently while eating eggshell, and 4 did not rest. With 19 of the larvae that passed through a distinct resting period, this period was interrupted with such activity as a reversal of position on the foothold, and with 7 no interruption occurred. The rest period of longest duration was 135 minutes, the least 3 minutes, and the average 29.6 minutes.

It is supposed that during the rest period the exoskeleton hardens thoroughly, and that this is usually a prerequisite to the following phase of activity.

MIGRATION TO THE EAR.—On resuming activity after resting, the larva explores for increasing distances from the egg and returns several times to the foothold, but eventually it departs and does not return. At this time it is much more active than during previous periods and moves rapidly over the corn silks, constantly laying down a sparse silken foothold as it travels. Usually the larva travels upward, but it often wanders back and forth and behaves as if confused by the maze of corn silks. A few individuals travel downward and reach the extremity of a silk strand, but finally reverse their direction. During migration larvae occasionally stop, explore to the right and left, and often crawl to

an adjoining silk strand. Eventually most larvae seem to orient themselves and crawl more directly upward, often with much crossing from strand to strand of silk. Although the larva might occasionally bite off and devour a seta at this time, such feeding seems to be only incidental to the main objective of reaching the tip of the ear as quickly as possible. The shortest period of migration observed was 8 minutes, the longest 98 minutes, and the average 29.6 minutes. Eventually the larva reaches the tip of the ear and gradually forces its way among the increasingly close-packed silk strands until lost to view.

Further observations of individual larvae could not be made without disturbing them, and their activity was determined by examination of corn ears after they had fed.

BEGINNING OF FEEDING.—Before larvae reach the tips of ears, the amount of plant feeding is negligible. The total number of setae eaten per individual ranged from 1 to 24, larvae rarely succeeding in biting into the exterior silk.

It is possible that newly hatched larvae migrate to the ear tip before feeding because they are in search of fresher food than is available exteriorly. Observations have shown, however, that larvae hatching in dark salve boxes fed on wilted silk and that larvae hatching from eggs placed on newly exposed silk migrated to the ear tip just as was done when the silks were older.

A more satisfactory explanation is that migration is a negative response to light. The larvae of this species seem to prefer to feed under the protection of plant parts. Furthermore, observations have shown that the individuals which did not migrate to the ear tip immediately after resting located on the exterior silks at places where many strands had tangled closely together. The light conditions of such tangles resembled those at the ear tips. Newly hatched larvae sometimes crawl deep among these tangled silk strands and remain there for prolonged periods.

The point where the larvae had begun to feed at the ear tip could usually be determined by examination of the ears. Of 100 ears of the variety Snowflake examined on March 27, in 54 ears feeding has occurred in the 10 millimeters of silk then lying just beyond the tip of the husk, and in 46 ears feeding had occurred only in the silk then lying within the tip of the husk. This evidence was not considered conclusive because in this variety the silk strands are pressed together very tightly within the husk at the tip, and larvae may have been unable to push their way inward. Furthermore, as the cob grows in length after pollination the interior silk mass may be forced outward and is gradually exposed beyond the husk tip.

After the corn ears have been removed from the plants and deprived of nourishment, it has been observed that the silks, except for wilting exteriorly, remain for several days as they were at the time of picking. Therefore, the place where feeding begins could be studied under controlled conditions. Ears were collected during the first week after silk exposure and were impaled on nails driven through boards so that they would remain upright. Newly hatched larvae were liberated on the exterior silks of these ears. After an interval of 24 hours the tips of the ears were examined under a binocular microscope. A study of the feeding by 118 larvae showed that 1.7 per cent had begun feeding on silk outside the husk, and the remainder on silk inside the husk at distances of 1 to 23 millimeters from the tip, the average location being 6.5 millimeters from the tip. Of the total number of larvae 49.2 per cent had begun feeding within the husk between 1 and 5 millimeters from the tip, 31.4 per cent between 6 and 10 millimeters, 11.0 per cent between 11 and 15 millimeters, 4.2 per cent between 16 and 20 millimeters, and 2.5 per cent beyond 20 millimeters.

In this study an important relationship was noted between the character of the husk and the location of first feeding by the larvae. In ears having loose husks, which did not press the silk strands together tightly, larvae crawled inward among the interior silk strands for considerable distances before beginning to feed. Progressively, as the husks were tighter and pressed the strands more closely together, the location of first feeding was more often in the silk at the husk tip, or just beyond in the adjoining exterior silk. In many ears of the variety Snowflake, the interior silk of which is very tightly pressed together, the larvae had begun to feed under cover of the tips

of the husk leaves extending the farthest upward. The constriction upon the silk at this point was less than that a few millimeters lower down, where the husk leaves overlapped. Apparently the newly hatched larvae often could not force themselves into the silk enclosed by the husk leaves, to which entrance was gained only by larger larvae and by them only by eating a passage through the silk mass.

RELATIONSHIP OF HABITS OF NEWLY HATCHED LARVAE TO CONTROL.—If efficient control of the corn ear worm on ear corn is to be obtained, every larva must be prevented from gaining access to the ear, since a single larva may cause damage of such seriousness as to make the ear unmarketable. The evidence presented shows that the amount of feeding by newly hatched larvae on the exterior silk is negligible, and it seems to indicate why insecticides applied to the exterior silks alone have proved to be ineffective. Even if an insecticide could be so efficiently distributed over the exterior silk that every silk strand and every seta were covered by it, the material would yet be ineffective against that portion of the larval population that ate no setae before migrating to the ear tip. The fact that newly hatched larvae concentrate within the tip of the ear to begin feeding suggested that they could be attacked at this point. Consequently methods of control by contact insecticides and fumigants were studied (Barber 1939).

SUMMARY.—Descriptions are given of the egg of the corn ear worm, *Heliothis armigera* (Hbn.), of the method of hatching, and of the habits of the larva from the time it emerges from the egg until it begins to feed on silk at the tip of the ear.

The average location of eggs on corn silk was 52.3 millimeters beyond the tip of the husk. The eggs were found to vary in size and shape, the smallest observed being somewhat more than half the volume of the largest.

The environment of the newly hatched larva on corn silk was found to be a veritable forest of silk and setae, through which it must find its way to the ear.

The time between hatching of the larva and arrival at the tip of the ear could be divided into three periods, namely, feeding period, resting period, and migrating period.

After completing emergence, and while clinging to a silken web that they spin for this purpose, most larvae devoured portions of the eggshell or a few setae in the vicinity. The average length of this period was 21.2 minutes. This activity was followed by a resting period, during which it is supposed the exoskeleton hardened. The average duration of this period was 29.6 minutes. The larvae then migrated to the ear tip where, protected by the encircling husks, they usually began to feed on the unwilted interior silks. The average duration of this phase was 29.6 minutes. The degree of tightness with which the interior silk strands were pressed together by the husk determined how far the larvae could force themselves within before beginning to feed.

Since newly hatched larvae feed very little on exterior silks, it is unlikely that efficient control can be obtained by applications of insecticides to the exterior silks alone. Introducing the insecticides into the tip of the ear, where the larvae collect to begin feeding, shows promise, however, as a control measure.—10-28-40.

LITERATURE CITED

Barber, G. W. 1939a. The use of oil for earworm control in sweet corn. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-476.

Barber, G. W. 1939b. Control of the earworm in sweet corn by fumigation. U. S. Dept. Agr., Bur. Ent. and Plant Quar. E-485.

Quaintance, A. L., and Brues, C. T. 1905. The cotton bollworm. U. S. Dept. Agr., Bur. Ent. Bul. 50.

The terminal inspection procedure for the inspection of parcel post shipments of plant material has been established in Minnesota. The classes of plants subject to such inspection are:

All wild and cultivated trees, shrubs, and woody vines; perennial roots, such as peonies and iris; small-fruit plants, such as strawberries and raspberries; herbaceous perennials, such as hollyhocks and other hardy flowering plants, cuttings, buds, grafts, and scions for, or capable of, propagation.

Breeding Places of the Stablefly or "Dog Fly" *Stomoxys calcitrans* (L.) in Northwestern Florida[1]

S. W. Simmons and W. E. Dove,[2]
U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine

The dog fly, or stablefly, *Stomoxys calcitrans* (L.), is a pest of exceptional economic importance to coast-resort activities and the livestock industry in the northwestern part of Florida. Under favorable conditions the insect may occur in large numbers from the middle of August to the middle of October in the littoral extending from the Alabama-Florida boundary line eastward 400 miles to Cedar Keys, Fla. In this area the heaviest concentrations of the flies occur within a section 200 miles long between Pensacola and Carrabelle. In summer and fall large numbers of flies may be found on this portion of the coast and inland from 5 to 35 miles, causing cattle to seek refuge in swamps, where many of them mire and die.

Until recently the source of these outbreaks has been a moot question. King & Lenert (1936) found breeding to occur in the marine algae of the genus *Sargassum*, located in tidal drifts along certain types of inlet beaches, and were of the opinion that this material might account for outbreak numbers of *Stomoxys* if the conditions observed proved to be of common occurrence.

Investigations of dog fly breeding places were begun by the senior author in the summer of 1939, when a laboratory was established at Panama City, with A. L. Brody in charge, and were continued throughout the following season, the junior author taking charge of the laboratory in August 1940. Observations were made over areas along the Atlantic and Gulf coasts.

In 1939 *Sargassum* was not found after studies were initiated at Panama City, but large numbers of dog flies appeared on September 11 of that year. Therefore it seemed certain that the flies emerged from a different material. In 1940 tidal drift deposits of *Sargassum* were observed only during late June and early July, which was about 6 weeks prior to the normal dog fly season. These deposits were not common and were found principally on the Gulf beaches, where they were disrupted by the tides and either returned to the water or scattered so thinly that they were dry and unsuitable for the breeding of *Stomoxys*.

During the years 1939–1940, when these preliminary observations were carried on, breeding of *Stomoxys* was found in different fermenting marine flora washed ashore on beaches and in peanut litter left in the fields where peanuts were harvested. The observations suggest that these two breeding conditions represent, in general, distinct problems which occur in different locations at different times of the year but which may prove to have a specific interrelationship.

Dog Fly Breeding in Bay Grasses.—Observations made intensively over extensive bay and sound beaches in Florida have shown that dog fly breeding along the northwestern coast occurs primarily in two species of bay grasses, *Halodule wrightii* Aschers, a long, narrow-bladed species known as shoalgrass, and *Thalassia testudinum* Koenig & Sims, which has long, straplike blades and is commonly known as turtlegrass. Both grow submerged in the water on the bottoms of certain portions of shallow bays and inlets in this region. Beginning about the first of August the blades of these grasses, which are at that time long and fragile, are broken off by the action of the water and are deposited in drifts on the beaches by the tides, where, under favorable conditions, they become heavily infested with dog fly larvae and pupae.

In bays along the Mississippi and Alabama coasts another type of wide-bladed species, *Vallisneria americana* Michx., or eelgrass, is found in locations having a low content of salt. When it is washed ashore in sufficient quantities it also constitutes an excellent breeding medium for dog flies. Heavy breeding was found in this material in October 1940, but the limited extent of bay beaches capable of receiving deposition of tidal drifts pre-

[1] The writers are indebted to E. E. Rogers for assistance in the early phases of this investigation, and to E. B. Blakeslee, J. B. Hull, and G. H. Bradley for field observations and assistance.

Read before Newell Entomological Society, Gainesville, Fla. March 27, 1941.

[2] Early publication of this paper has been secured by payment of the costs of printing.

vented any extensive breeding in this kind of grass. There are undoubtedly other varieties of marine flora which could breed dog flies if washed ashore in sufficient quantities when flies are present to lay eggs.

Limited breeding was found in tidal drifts of the marine alga *Entermorpha plumosa* Kuetzing. This species had been brought in by tides from the Gulf in July and deposited in thin sheets on the shore of an isolated bay beach. When the crust of the partly dried material was broken, to permit flies to reach the moist portion, it became infested and produced dog flies. Since the quantity of this material is limited, and since most of it is spread in thin sheets and therefore does not retain sufficient moisture for favorable breeding of large numbers of flies, this species is relatively unimportant as a source for outbreak numbers.

DEVELOPMENT OF THE DOG FLY IN BAY GRASSES.—Under favorable conditions the development of the dog fly in bay grass was found to be very rapid. On May 18, 1940, approximately 1,000 newly hatched larvae were placed in a battery jar containing 1 gallon of *Thalassia testudinum* mixed with a small amount of *Halodule wrightii*, which had been collected green 2 days previously. The material was incubated at 32° C. and in 5 days pupae were present. The jar was then transferred to room temperature and in 5 additional days some normal flies emerged. These flies laid fertile eggs when 12 days old and some of them lived for 22 days. A portion of the same lot of grass, which had been infested on the date of collection, produced pupae in 7 days, and flies emerged 6 days later. In other rearing tests with the same kind of medium adult flies were produced within 13 or 14 days subsequent to infestation. These results compare favorably with those obtained with Richardson's medium as modified by Doty (1937). When flies were reared in this medium at 28° C., the mean minimum larval and pupal periods were 7.0 and 7.6 days, respectively.

In more than 45 piles of green *Thalassia testudinum* and *Halodule wrightii* exposed near a cattle corral, good infestations were readily obtained. One of the exposures of 9 cubic feet of *T. testudinum* was wet with 25 gallons of fresh water on September 6. On September 9 the first eggs were noted and 13 days later normal adults emerged. Emergence continued from this lot for 38 days and a total of 742 adult flies emerged, or on an average 82.4 flies per cubic foot. In naturally exposed *H. wrightii* development was slightly slower, with an emergence of 38.7 flies per cubic foot of grass. A greater density of breeding was obtained from an exposure of *Vallisneria americana*, which produced 167 flies per cubic foot. The average time from exposure of grass to emergence of flies for 12 lots during September was 20.4 days. For flies reared in the laboratory on Richardson's medium and kept in captivity the greatest life span was 47 days, with an average maximum of 18.3 days. The average preoviposition period was 11 days.

Development in the bay grasses was found to vary considerably with the temperature and the condition of the grass. The minimum period from deposition of the egg to emergence of the fly was 13 days, the average from 20 to 25 days, and the maximum observed 116 days. During unfavorable temperature conditions longer periods undoubtedly occur.

NATURAL FACTORS WHICH INFLUENCE BREEDING IN BAY GRASS.—Abnormally high storm tides lay down rows of the bay grasses *Thalassia testudinum* and *Halodule wrightii* high above the normal tide lines, making them beyond reach of the normal daily tides which follow and free to develop infestations of dog flies.

If grasses are deposited on the beaches by normal tides, subsequent tides partially inundate them with salt water, thus preventing normal fermentation and rendering the submerged portions unsuitable for development of larvae. When grasses are infested and then inundated repeatedly by high tides, most of the larvae are destroyed. Those reaching the third instar often pupate prematurely, as a matter of self-preservation, and therefore small, ill-formed pupae are found. These produce flies that are invariably small and weak.

The normal breeding of *Stomorys* in bay grasses is restricted to rather green material that undergoes active fermentation. When first instars were implanted on *Thalassia testudinum* which had been used to rear one generation of flies, and which had passed the active stage of fermentation, the larvae did not develop. Natural deposits of old grasses on beaches, of both

T. testudinum and *Halodule wrightii*, which had passed the active fermentation stage, were usually uninfested or contained a relatively small number of undersized larvae and pupae, and any flies emerging from them were invariably small.

Along the Florida coast in 1940 dog flies were much less abundant than in previous years. During that year there was a total absence of summer storms, which break off the grass blades and deposit them in rows high upon the beaches. These deposits were made at the normal high-tide mark prior to the equinox of September 21, and therefore preceding the high tides of this equinoctial period. The grass deposited at the high-tide mark on one day would be below the high-tide mark of following days and thus subject to inundation.

In 1939, however, storm tides during August deposited large quantities of grass high upon the beaches and a major outbreak of dog flies followed. Such an occurrence is usual along the coast of northwestern Florida and is to be expected.

Usually no appreciable quantities of grasses are deposited prior to August and the earliest dog fly outbreaks seldom occur before the middle of this month. After September green grasses are rarely deposited, because at this time the blades begin to turn brown and die in position at the bottoms of shallow bays. Conditions then are not suitable for fly breeding. By November a considerable portion of the grass blades are dead and most of them are covered with a film of mud. Even when they are pulled from the bottom of the bay they are found unsatisfactory for breeding dog flies.

Biological factors are undoubtedly of some importance in reducing the dog fly population. Ants have been observed to carry away considerable numbers of eggs deposited in bay grasses, and several species have been observed feeding on eggs, one of which has been identified as the fire ant, *Solenopsis geminata* (F.).

A predacious wasp, *Vespula squamosa* (Drury), was very active during October and November, 1940, and was observed to destroy many adult dog flies about the laboratory premises. For a short time the wasp reduced the local population to a point where it was difficult to obtain sufficient eggs on bay grasses for biological study. The horse guard, *Stictia carolina* (F.) is another predacious wasp which appears during the spring months and may destroy many of the flies. A predacious bee, *Xylocopa micans* (Lep.) was observed capturing adult flies in the spring of 1941.

FACTORS WHICH LIMIT INFESTATIONS.—Extensive investigations of both the infested area and the adjacent relatively uninfested areas revealed some factors which are responsible for limitations of dog fly distribution.

A survey of the littoral along the Gulf in Alabama and Mississippi during October 1940 indicated that the absence of extensive dog fly outbreaks in this area was due principally to (1) the scarcity of suitable bays for the production of bay grasses, there being only St. Louis Bay and Biloxi Bay along the Mississippi coast, both of which are comparatively small, and only Mobile Bay on the Alabama coast; and (2) the fact that there is almost an absence of beaches along these bays for grass deposition. This was especially true of bays along the Mississippi coast, where the shore line is overgrown with black rush, *Juncus roemerianus* Scheele, and cord or tide grass, *Spartina alterniflora* Loisel. The growth of both grasses often extends below the water line, eliminating open beaches and forming a barrier against tidal drifts.

The bay grasses in this region are different from those west of Mobile, Ala. *Vallisneria americana* is the predominating species in the latter area and *Thalassia testudinum* and *Halodule wrightii* were not found. Small (1933) lists *V. americana* as a fresh-water herb, but Martin & Uhler (1939) state that it grows in water having a salt content up to 28 percent of normal sea salinity. The bays along the Missisippi Sound are much less salt than those of western Florida. None of them showed a specific gravity of over 1.010 at 27° C. even near their opening into the sound. Nearer the central and upper portions of the bays, where the growth of *V. americana* is most luxuriant, the salt content was found to be even less. As a comparison the water in St. Andrews Bay at Panama City tested 1.021, which is equivalent to about twice the salt content of the Mississippi Sound bays and slightly more than that of the sound.

The water of the small Mississippi bays should be less turbulent during storms

than that of the larger bays in the dog fly territory, and therefore less likely to break off large quantities of grass, which might be deposited on shore.

In many respects the Mississippi Sound is much like a bay, but examinations made along its entire shore line in November 1939 and October 1940 revealed no tidal drifts of grasses, nor was any appreciable quantity of grasses found growing on its bottom. An alga, *Chondra* sp., was rather common in the sound, sometimes being deposited in small quantities on shore but never found to be breeding dog flies.

Mobile Bay possesses more sand beaches than bays along the Mississippi Sound, and there breeding was observed in small deposits of the same species of bay grasses that occur in western Florida. This bay possesses more potentialities for extensive dog fly breeding than the sound bays. The fly population is limited, however, along its shores by the relatively small quantity of grass depositions and the small number of beaches available for tidal deposits.

Along the Gulf coast of Florida southeast of Carrabelle, and as far south as Everglades, surveys indicated that the factors limiting dog fly breeding were of the same general nature as those observed along the Mississippi Sound. This region does not have numbers of extensive inland bays like those in northwestern Florida. Open bays occur which are really broad extensions of the Gulf projecting into the mainland. These may produce large quantities of both *Thalassia testudinum* and *Halodule wrightii*, and in many places also *Ruppia maritima* (L.), or wigeongrass. Along the entire coast line from Carrabelle to a point near Tampa mud flats occur which are frequently inundated by tidal water. They contain some tall growing *Juncus roemerianus*, which serves as a barrier to prevent deposition of bay grasses and indirectly to limit the breeding of dog flies. High tides sometimes pile drifts of the grasses on the bent-over *J. roemerianus* growing along the water line, and in some unprotected places grasses are deposited on the beach. These breeding places would seem to explain the origin of serious dog fly outbreaks that occasionally occur in these regions.

South of Tampa and in inlets, sounds, and bays along the Atlantic coast of Florida *Halodule wrightii* is rather commonly found, but its deposition on shore in most of the region is effectively barred by the absence of a suitable beach and by the dense growth of red mangrove along the water line. Thick mangrove roots are apparently an even more effective barrier than shore grass, and dog flies are hardly known along beaches in this area.

DOG FLY BREEDING IN PEANUT LITTER.—In northwestern Florida, as well as in southeastern Alabama and southwestern Georgia, dog flies were found to breed extensively in piles of peanut litter left in the field after picking and baling operations were completed. In December 1940 cattle suffered severely, and in Walton County, Fla., some young pigs died from the fly attacks. This unusual emergence occurred in and immediately following an exceptionally warm period, and from pupae that were dormant during the preceding cool weather. According to county agents and farmers bad outbreaks are annual occurrences.

A general practice in this section is to stack the peanut vines at various points in the field, where the peanuts are picked by machine and the vines are baled for hay. At each of these locations considerable litter, consisting of leaves, broken stems, and peanuts, remains on the ground when these operations are finished. An average pile of litter ranges in diameter from about 25 to 30 feet, and in depth from an inch near the edges to as much as 3 feet or more in the center. Each pile of litter represents the location where peanuts from about 10 harvested acres are picked, and where the peanut vines from the same area are baled for hay. When this litter receives rain it ferments and is then an ideal breeding place for dog flies. Under favorable conditions there may be more than 100 larvae and pupae per square foot of litter. It is estimated that 36 square feet of undisturbed litter in a cage produced approximately 10,000 adult flies within 48 hours.

According to estimates based on the best available data there were in 1940 about 1,000,000 acres of peanuts harvested in 52 adjoining counties, and a considerable amount of harvesting took place throughout neighboring and other counties. Dog fly breeding was found in every pile of litter examined in 10 counties of northwestern Florida, which had an

area of about 70,000 harvested acres; in 9 counties of southeastern Alabama, having about 300,000 harvested acres; and to a limited extent in some of the 33 counties of southwestern Georgia, which had approximately 630,000 harvested acres. A total of 100,000 piles of litter in the principal peanut-growing areas of the three states is a conservative estimate. Records of harvested acreages for different years show that in most counties such acreage is increasing annually, and that many counties which have not been growing peanuts are now beginning to cultivate them.

In some of the litter piles examined breeding was found to be fairly uniform, but in very large piles it was often confined to the edges where the litter had been wet from the upper surface to the ground. In such piles the deep central portion was dry, but during wet years it would be capable of fermenting and vastly increasing breeding.

Intensive hogging of litter piles may aid in reducing the infestation, by causing dirt to be mixed with the litter, which cuts off the food supply from the immature larvae, and by exposing both larvae and pupae to natural enemies and to adverse weather conditions. This practice, however, can not be relied upon as a control measure, because the hogs cause new openings in the litter to be exposed to infestation, whereas many mature larvae and pupae already present are covered only sufficiently to retard the emergence of adults until a later time.

ELIMINATION OF POTENTIAL BREEDING IN PEANUT LITTER.—Since infestation by dog fly larvae and pupae may be found throughout the piles of wet fermenting litter, with the possible exception of the very deep portions, the entire piles should be considered as potential breeders of dangerous numbers of dog flies.

It is recommended that all piles of litter be scattered over the fields and plowed under as fertilizer immediately after harvest. If this is not done the piles of litter should be scattered at their present location and immediately plowed under. If the litter is stored, under cover as feed, such portions of the piles as remain on the ground should be plowed under immediately. If litter is removed to shelter and fed to animals each day, the material wasted on the ground near the feed trough should be cleaned up, hauled to the fields, and scattered thinly each week to permit complete drying.

DISPOSITION OF INFESTED PEANUT LITTER.—It is more satisfactory to scatter and plow under litter immediately after harvest before this material has an opportunity to become infested than to dispose of the litter after it becomes infested. In any event breeding should be reduced to the lowest degree, since any pile of peanut litter that remains in the fields without attention can produce more than 100,000 dog flies.

If the infested litter is distributed thinly over the land and allowed to dry, immature larvae will be destroyed and many pupae will die from exposure. Some pupae when exposed on the surface of the soil will emerge on warm winter days, but most of the flies will not survive subsequent cold periods.

By the time litter piles become infested and mixed with soil as a result of rooting by hogs, it may be necessary to scatter them with a shovel instead of a pitch fork, because they are partly decayed and do not hold together well. All infested soil and litter should be loaded on a wagon or a manure spreader, and scattered.

It is *not* recommended that this material be plowed under after it becomes infested with full grown larvae and pupae, because this practice would simply delay emergence of the flies until later. When the soil becomes warm newly emerged adults easily push through 4 to 6 inches of sandy soil, and one-third of the normal emergence occurred when pupae were buried eight inches deep.

SUMMARY.—The dog fly occurs in outbreak numbers from the middle of August to the middle of October in the littoral extending from the Alabama-Florida boundary line eastward 400 miles to Cedar Keys, Fla. Because the pest is important in all temperature climates and seriously affects resort activities and livestock in northwestern Florida, investigations were undertaken at Panama City in the autumn of 1939 for the purpose of determining a basis for controlling this pest.

During preliminary observations in 1939 and 1940 summer breeding of the pest was discovered principally in fermenting tidal deposits of *Halodule wrightii* and *Thalassia testudinum*, on bay shores, where it was sometimes affected adversely by

the occurrence of tidal inundations.

Late autumn breeding of the pest was discovered in fermenting piles of peanut leaves and stems left in the fields where picking and baling operations were completed. Approximately 1,000,000 acres of harvested peanuts in 52 counties are represented by approximately 100,000 piles of litter, ranging from about 25 to 30 feet in diameter.

The discovery of the two types of extensive breeding places show the need for preventing development of flies in such places.—5-28-41.

LITERATURE CITED

Doty, A. E. 1937. Convenient method of rearing the stable fly. JOUR. ECON. ENT. 30 (2): 367–9.

King, W. V., and Louva G. Lenert. 1936. Outbreaks of *Stomoxys calcitrans* L. ("dog flies") along Florida's northwest coast. Fla. Ent. 19 (3): 33–9.

Martin, A. C., and F. M. Uhler. 1939. Food of game ducks in the United States and Canada. U. S. Dept. Agr. Tech. Bul. **634.**

Small, John Kunkel. 1933. Manual of the southeastern flora. 1554 pp. New York.

The Toxicity of Alkyl Secondary Amines to the Housefly[1,2]

PAUL A. DAHM and C. W. KEARNS, *University of Illinois, Urbana*

The object of most investigations concerning the insecticidal properties of synthetic organic compounds, aside from the discovery of compounds of practical value as insecticides, should be the discovery of relationships between molecular structure and insect toxicity. Many investigations frequently involve several different types of compounds and only a very small percentage of the many possible compounds of any one type are represented. Such investigations may result in the chance discovery of a commercially practical compound or the conclusion that certain groups or types of compounds offer more promise than others. In either case very little information has been contributed toward our better understanding of the relationship of molecular structure to insect toxicity, unless a logically selected representative series of compounds is evaluated for each type of compound chosen as having interesting toxic properties.

Since we were primarily interested in studying the relationship of molecular structure to insect toxicity, we decided to limit our investigation to a single homologous series of compounds; namely, alkyl secondary amines. These compounds are of interest, from our point of view, because they represent a series of compounds in which one may assume that their toxicity is largely due to the presence of the —(NH)— group. This seems logical because the corresponding hydrocarbons in the paraffin series are known to be practically non-toxic to insects when applied at normal concentrations. Therefore, variations in the toxicity of closely related compounds in alkyl secondary amines may be considered to be due to minor differences in the size and structure of the alkyl groups, and not due to the introduction of other functional groups which might conceivably contribute an additional toxic property to the molecule.

The housefly was chosen as a suitable test insect for the following reasons. First, it is easy to rear in large numbers under standardized conditions. Second, the compounds can be applied as the free bases dissolved in hydrocarbon solvents, thereby avoiding uncontrollable variations which would have been encountered if the compounds had been applied in aqueous emulsions. Third, because the housefly provides a means of estimating the relative rates at which the various compounds act upon the insect, as evidenced by the time required to produce a certain percentage "knockdown."[3]

METHODS.—The houseflies used in these tests were reared according to specifications given in "Soap Blue Book" (1939) for the "Peet-Grady" testing procedure. The tests were likewise conducted in ac-

[1] Contribution Number 221 from the entomological laboratories of the University of Illinois.

[2] Early publication of this paper has been secured by payment of the costs of printing.

[3] The term "knockdown" is applied to flies on the floor of the chamber which have lost their ability to fly or walk in a normal manner.

cordance with the specifications of the "large group Peet-Grady" procedure except that occasionally the official test insecticide was substituted by another compound, which was known to produce a comparable percentage mortality at a certain concentration. This was done only in instances where a compound of known toxicity was directly compared with a compound of similar structure but unknown toxicity.

In all cases five or more tests were made upon each compound at a concentration which would produce a mortality percentage suitable for comparison purposes. With all the amines the percentage of moribund flies observed 24 hours after treatment was appreciable, usually varying from 10 to 20 per cent. We have considered only the percentage mortality in evaluating the compounds, because this figure was apparently subject to less variation than one which included the percentage moribund. Where several compounds used at the same concentration produced mortality percentages which were not significantly different, they were grouped together and tested in a series of replications upon the same culture of flies. If significant differences could not then be ascertained, these compounds were considered to be approximately equal in toxicity or else beyond the accuracy of the method used to enable distinction.

The rate of effectiveness of various compounds was estimated by the time required, following the spray application, to produce a "knockdown" of approximately 95 per cent of the flies. This time interval could not be determined accurately within the space of one minute, for any one compound, and probably would be of no particular significance if there had not been a great variation in the rate at which the various compounds affected the housefly.

Except in a few instances where certain compounds could be obtained from the pure stocks of various chemical companies, the compounds used in this investigation were prepared by us, Mr. Arthur Toy, and Mr. Clifford Shunk. In cases where it was necessary for us to prepare primary amines they were made by the high pressure reduction aminolysis of the corresponding ketone or aldehyde, as described by Schwoegler & Adkins (1939). The preparation of the secondary amines was accomplished by the usual method of reacting the alkyl halide with a slight excess of the primary amine. The compounds were purified by careful fractional distillation of the free bases under reduced pressure. The compounds are all known to be of high purity, and differences in the toxicity of closely related compounds are due, therefore, to minor differences in chemical structure and not to impurities.

DISCUSSION.—Several of the compounds included in our study have recently appeared in a publication, by Ralston *et al.* (1941), upon the toxicity of fatty acid derivatives to the housefly. The results obtained by these writers agree to a certain extent with our results where the same compounds are involved. The main discrepancies are probably due to the fact that we each used different testing procedures, and in the case of their method, the differences in toxicity between closely related compounds are less pronounced. The only other publication which may have a bearing upon our work is the recent publication of Hoskins *et al.* (1940) in which the toxicity of three alkyl secondary amines was determined for fleshfly larvae. In this case the writers discovered that a lower member of this series—namely, di-*n*-butylamine—was the most toxic. We found the opposite relationship to exist in the case of the adult housefly; that is, the lower members of the alkyl secondary amines are much less toxic than the higher members.

All the compounds used in our study are listed in table 1, with information concerning the refractive index, specific gravity, boiling point, toxicity, and the rate of toxic action of each compound. On the basis of their chemical structure the compounds may be conveniently considered to be of three different types, distinguished as follows. One type whose structure is represented as R—(NH)—R where R represents a straight chain alkyl group; a second type represented as R—(NH)—R′ where R′ represents a branched chain alkyl group; and a third type, R′—(NH)—R′, where both alkyl groups are branched chains. The comparisons which follow, therefore, involve an estimation of the effects of the size of the alkyl groups within each type, as well as an estimation of the effects of structural configuration represented by the three different types of compounds.

The compounds 1 to 13 inclusive which

Table 1.—The toxicity and rate of action of alkyl secondary amines to the housefly.

No.	Compound	n_D^{20}	Sp. G.	B. P. °C.	Ave. Per Cent Mortality (5 per cent by weight)	Ave. K. D. T.[6] in Minutes
1.	Di-*n*-propylamine[1] $(C_3H_7)_2NH$	1.4046	0.741	105–109	—[3]	—[3]
2.	Di-*n*-butylamine[1] $(C_4H_9)_2NH$	1.4186	0.767	161	—[3]	—[3]
3.	Di-*n*-amylamine[5] $(C_5H_{11})_2NH$	—	—	—	7	10+
4.	Di-*n*-hexylamine $(C_6H_{13})_2NH$	1.4347	0.7867	101–103/ 25 mm.	58	4.5
5.	N, *n*-hexyl-*n*-heptylamine $C_6H_{13}NHC_7H_{15}$	1.4364	0.7887	105/2 mm.	81	3.9
6.	N, *n*-amyl-*n*-octylamine $C_5H_{11}NHC_8H_{17}$	1.4370	—	96–97/ 2 mm.	64	5.2
7.	N, *n*-butyl-*n*-nonylamine $C_4H_9NHC_9H_{19}$	1.4377	0.8133	102–106/ 3 mm.	45	6.2
8.	N, *n*-propyl-*n*-decylamine $C_3H_7NHC_{10}H_{21}$	—	—	91–94/ 2 mm.	13	10+
9.	Di-*n*-heptylamine $(C_7H_{15})_2NH$	1.4393	0.7949	122/3 mm.	73	5.3
10.	N, *n*-heptyl-*n*-octylamine $C_7H_{15}NHC_8H_{17}$	1.4408	0.7979	123–126/ 2 mm.	80	4.8
11.	Di-*n*-octylamine[4] $(C_8H_{17})_2NH$	1.4430	0.8019	128–133/ 1 mm.	77	8.3
12.	N, *n*-hexyl-*n*-decylamine $C_6H_{13}NHC_{10}H_{21}$	1.4467	0.8075	—	61	10.
13.	Di-*n*-decylamine[5] $(C_{10}H_{21})_2NH$	—	—	—	12	10+
14.	N, *n*-hexyl, 2-aminoheptane $C_6H_{13}NHCH(CH_3)C_5H_{11}$	1.4392	0.7916	117–119/ 8 mm.	71	5.1
15.	N, *n*-hexyl, 4-aminoheptane $C_6H_{13}NHCH(C_3H_7)C_3H_7$	1.4333	0.7880	82–83/ 1 mm.	31	7.4
16.	N, *n*-hexyl, 2-aminooctane $C_6H_{13}NHCH(CH_3)C_6H_{13}$	1.4385	0.7932	95–96/ 1 mm.	48	5.9
17.	N, *n*-heptyl, 2-aminoheptane $C_7H_{15}NHCH(CH_3)C_5H_{11}$	1.4368	0.7923	96–97/ 2 mm.	49	5.6
18.	N, *n*-heptyl, 4-aminoheptane $C_7H_{15}NHCH(C_3H_7)C_3H_7$	1.4362	0.7939	97–98/ 3 mm.	46	7.2

Table 1.—Continued

No.	Compound	n_D^{20}	Sp. G.	B. P. °C.	Ave. Per Cent Mortality (5 per cent by weight)	Ave. K. D. T.[6] in Minutes
19.	N, *n*-heptyl, 2-aminooctane $C_7H_{15}NHCHC_6H_{13}$ (CH₃)	1.4410	0.8010	112–113/ 4 mm.	61	5.9
20.	Di-*iso*-butylamine[3] $\left(\begin{matrix}CH_3CHCH_2\\ \quad\quad|\\ \quad\quad CH_3\end{matrix}\right)_2NH$	1.4090	0.746	136–140	—[3]	—[3]
21.	Diamylamine $(C_5H_{11})_2NH$[1,2]	1.4259	0.77–0.78	202–203	4	10+
22.	Di-(2-ethyl-*n*-hexyl) amine[1] $(C_4H_9CHCH_2)_2NH$ (C_2H_5)	1.4462	0.802	120–122/ 2 mm.	—[3]	—[3]

[1] Sharples Solvent Corporation.
[2] A mixture of various amyl isomers.
[3] Poor knockdown, no accurate evaluation possible for 5% conc. of compound.
[4] Armour and Company.
[5] Organic Manufactures Laboratory, University of Illinois.
[6] K.D.T. = Time required to produce 95 per cent knockdown.

are listed in table 1 are all of the R—(NH)—R type. Of these compounds, those having the same number of carbon atoms in both alkyl groups or differing by only one carbon atom show a progressive increase in toxicity and rate of action as the number of carbon atoms in the molecule is increased from 6 to 13. The members of this series below di-n-amylamine are not sufficiently toxic to produce any appreciable mortality or knockdown within a ten-minute period following treatment when used at a concentration of 25 per cent. The toxicity and rate of action of the compounds having identical alkyl groups or differing only by one carbon atom are graphically illustrated in figure 1. It will be noted that the compound N-*n*-hexyl-*n*-heptylamine and the higher members of the series up to and including di-*n*-octylamine form a group which is outstanding in toxicity. The rate of toxic action, however, decreases in the compounds higher in the series than N-*n*-hexyl-*n*-heptylamine.

Upon the basis of high toxicity and rapid rate of action the compound N-*n*-hexyl-*n*-heptylamine is superior to all the others. It occurred to us that other compounds of the R—(NH)—R type having the same empirical formula might be equivalent in toxicity and rate of toxic action. So three other compounds of the R—(NH)—R type having the same empirical formula, $C_{13}H_{29}N$, were prepared

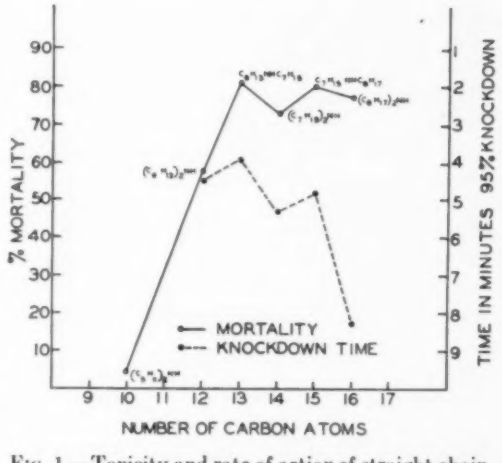


FIG. 1.—Toxicity and rate of action of straight chain alkyl secondary amines. At concentration of 5 per cent by weight.

and evaluated in comparison with N, *n*-hexyl-*n*-heptylamine. The results of these tests are recorded in table 1 as compounds 5, 6, 7, and 8, and are graphically illustrated in figure 2, there it will be seen that the toxicity and the rate of toxic

action appear to decrease linearly as the difference in the number of carbon atoms in the two alkyl groups varies from 1 to 7.

Compounds of the R—(NH)—R′ type were prepared to determine the toxic effects of a branched-chain alkyl group in comparison with that of a straight-chain group. The compounds of this type are recorded in table 1 as numbers 14 to 19

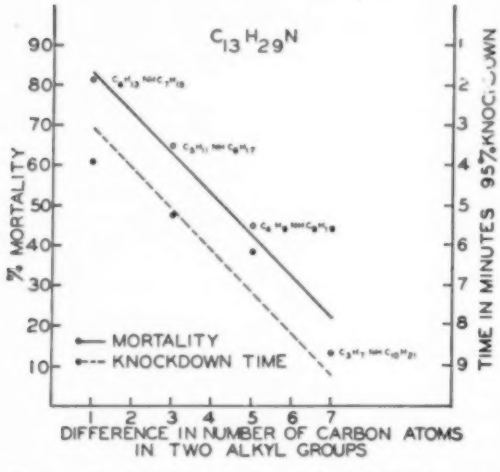


FIG. 2.—Toxicity and rate of action of N-*n*-heptyl *n*-hexylamine and certain of its straight chain isomers. At concentration of 5 per cent by weight.

inclusive. In all cases the toxicity of the branched chain compounds is lower and their rate of action slower than their straight chain isomers. The number of carbon atoms in the longest possible chain of branched-chain alkyl groups apparently has an important bearing upon the toxicity of the compounds. That is, branched-chain alkyl groups having a greater number of carbon atoms in a straight chain contribute more toxicity to the compound. This statement is substantiated by the fact that derivatives of 2, aminoheptane, are more toxic than corresponding derivatives of 4, aminoheptane.

Only three compounds were tested which represent the R′—(NH)—R′ type, in which both alkyl groups are branched chains. The compounds of this type are listed in table 1 as numbers 20, 21, and 22. The results of tests with these compounds substantiate previous statements made regarding the effect of a branched-chain alkyl group. In this case the drop in toxicity is of considerable magnitude and is strikingly illustrated by a comparison of the toxicity of di-*n*-octyl amine which produced a 77 per cent mortality at a 5 per cent concentration as compared with that of its branched-chain isomer, di-(2, ethyl-*n*-hexyl) amine which did not produce any appreciable mortality at a concentration of 25 per cent.

SUMMARY.—We have investigated the toxicity and rate of toxic action of 22 alkyl secondary amines to the housefly. The "large group" Peet-Grady method was used in making the tests. In the group of straight-chain alkyl secondary amines, we found the compound N, *n*-hexyl-*n*-heptylamine to be the most rapidly acting compound, as judged by the time required to produce approximately 95 per cent knockdown. This compound likewise is more toxic than any lower members of the series and equal or superior to any of the higher members. Straight chain alkyl secondary amines, having identical alkyl groups or differing by only one CH_2 group, are more toxic than isomers in which the two alkyl groups differ by a greater number than one CH_2 group. Branched-chain alkyl groups substituted for a straight-chain alkyl group produce a reduction in toxicity and a decrease in the rate of toxic action.—5-28-41.

LITERATURE CITED

Hoskins, W. M., H. P. Bloxham, and M. W. Van Ess. 1940. The insecticidal effects of organic compounds. JOUR. ECON. ENT., **33**(1): 875–80.

Blue Book. 1939. "Peet-Grady Method" Soap, **11**: 177–82.

Ralston, A. W., J. P. Barrett, and E. W. Hopkins. 1941. The insecticidal properties of some fatty acid derivatives. Oil and Soap, **18**(1): 11–3.

Schwoegler, E. J., and H. Adkins. 1939. Preparation of certain amines. Jour. Am. Chem. Soc., **61**(8): 3499–505.

SCIENTIFIC NOTES

Proportion of the Sexes in June Beetles in Wisconsin

T. R. Chamberlin and Lee Seaton, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

As a rule more male than female June beetles are attracted to lights and are caught in light traps. This fact suggests that males may be more numerous in nature. A large number of records of male and female bettles collected from food plants over a period of years should give a reliable basis for determining the sex ratio of the beetles. The few published records are as follows:

Forbes (1907) reported that of 3,479 June beetles collected from trees in Illinois in 1906 39.01 per cent were males. Most of the beetles belonged to the species *Phyllophaga implicita* (Horn), and over two-thirds of these were females. Other species included *P. ilicis* (Knoch) 241 and *P. hirticula* (Knoch) 242, 42.52 and 43.80 per cent being females.

McCulloch & Hayes (1922) list by sex the June beetles of various species collected from *Crataegus* sp. in the vicinity of Manhattan, Kans., from 1917 to 1920. Of 4,071 beetles 55.61 per cent were males. *Phyllophaga rubiginosa* (Lec.) comprised 92.78 per cent of the total beetles.

The collection records of June beetles given below, some of which have been treated in other publications (Chamberlin *et al.* 1938, 1939), consist of all those made in Wisconsin by the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in cooperation with the Wisconsin Agricultural Experiment Station, during the years 1935–40. The beetles were taken by hand picking or shaking from host plants. Approximately 237 collections were made in the six seasons.[1] The data are shown in table 1.

Table 1.—Collections of June beetles from host plants in Wisconsin, 1935–40.

Species of Phyllophaga	Total Number Caught	Per Cent Males
P. hirticula (Knoch)	21,238	52.4
P. rugosa (Melsh.)	18,314	49.1
P. fusca (Froel.)	10,704	44.1
P. implicita (Horn)	1,626	40.1
P. tristis (Fab.)	1,571	43.1
P. ilicis (Knoch)	1,015	56.8
P. prunina (Lec.)	752	45.9
P. drakei (Kby.)	559	43.7
P. futilis (Lec.)	376	66.5
P. balia (Say)	372	42.2
P. nitida (Lec.)	295	55.9
P. crenulata (Froel.)	124	56.5
P. anxia (Lec.)	77	52.0
P. marginalis (Lec.)	53	49.1
P. spreta (Horn)	19	47.4
P. inversa (Horn)	10	60.0
P. forsteri (Burm.)	5	60.0
P. villifrons (Lec.)	1	100.0
All species	57,111	49.2

Regarding these collections certain facts not shown in table 1 should be pointed out. All species of June beetles in the same locality do not begin emergence at the same time in the season. Generally speaking, there is a tendency for males to be more abundant early in the season and for females to persist later. Apparently, also, females during the preoviposition and early oviposition periods emerge and feed in greater numbers at lower temperatures than do the males. It is evident therefore that a few collections, however large, may give erroneous figures as to the relative proportions of males and females in the field at large, and that if reliable figures are to be obtained many collections must be made and these distributed throughout the entire feeding period and over at least several seasons.

A total of 57,111 beetles were taken, of which 49.16 per cent were males. Of the Phyllophaga in southern Wisconsin it may be stated therefore that male and female beetles occur in approximately equal numbers. There is some difference, however, in the proportions of the sexes in the different species. *P. hirticula*, *P. rugosa* and *P. fusca* together comprised 88 per cent of all beetles collected. The sexes were about equally divided in *rugosa;* there was a slight excess of males in *hirticula* and a somewhat larger excess of females in *fusca.* Regarding the other less common species, there was an excess of females in *tristis*, *implicita*, *prunina*, *drakei*, and *balia* and of males in *ilicis*, *futilis*, and *nitida.* The preponderance of females in *implicita* and males in *ilicis* agrees with the results of Forbes (1907).

It was noted in 1938, when most of the *ilicis* beetles were collected, that this species differed markedly from most of the others in regard to the time in the season when males or females predominated. As stated above, as a general rule males predominate early in the season and females later. With *ilicis*, however, the males predominate as the season advances. In 1938 the number of males began to exceed the number of females about the first of June, and this condition lasted until July 10, when the period of major flight was long past.—4-11-41.

Literature Cited

Chamberlin, T. R., C. L. Fluke, Lee Seaton, J. A. Callenbach and P. O. Ritcher. 1938. Population and host preferences of June beetles in southern Wisconsin in 1935, 1936, and 1937. U. S. Dept. Agr., Bur. Ent. and Plant Quar., Insect Pest Survey Bul. **18**(4): 225–40.

Chamberlin, T. R., C. L. Fluke, Lee Seaton, and J. A. Callenbach. 1939. Populations and host preferences of June beetles in southern Wisconsin in 1938. U. S. Dept. Agr. Bur. Ent. and Plant Quar., Insect Pest Survey Bul. **19**(3): 103–9.

Forbes, S. A. 1907. On the life history, habits, and economic relations of the white-grubs and May-beetles (Lachnosterna). Ill. Agr. Expt. Sta. Bul. **116**: 447–80.

McColloch, J. W., and Wm. P. Hayes. 1922. The Phyllophaga (Scarab. Coleop.) of hawthorn (Crataegus). Brooklyn Ent. Soc. Bul. **17**(5): 131–5.

[1] The authors were assisted in the collecting by J. A. Callenbach, C. L. Fluke, P. O. Ritcher, and temporary assistants.

Effect of pH on Toxicity of Certain Antimony Compounds to the Greenhouse Thrips

C. O. PERSING, B. R. BARTLETT, and R. L. BEIER,
University of California, Riverside

Work at the Citrus Experiment Station on control of citrus thrips, *Scritothrips citri* (Moult.), has led to an extensive use of sprays containing potassium antimony tartrate (tartar emetic) for this purpose.

The project has included a study of various related antimony compounds that might be of value as substitutes for tartar emetic. This phase of the project has assumed a considerable degree of practical importance in recent months because of conditions that have not only caused a substantial increase in the price of tartar emetic but also suggest a possibility of a serious shortage of the material in the future.

From the standpoint of availability and effectiveness, potassium antimony citrate offers promise as a substitute for tartar emetic. Extensive field experiments in 1940[1] demonstrated that this material was fairly effective for control of the citrus thrips, but it was not as effective as tartar emetic even when used at twice the tartar emetic dosage. In the course of tthes experiments it was noted that in the field of pH of the tartar emetic spray solutions was usually in the region of 6.1, whereas the pH of spray solutions of potassium antimony citrate was in the region of 4.4. This suggested that the difference in effectiveness between these two materials might be due to the pH of the spray solutions. Therefore a laboratory study has been undertaken to determine the effect of pH and the presence of various salts naturally occurring in spray waters on the toxicity of these materials.

The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché), is used as a laboratory test insect in this study. This species is well adapted for this purpose since it is very easily reared and handled in large numbers in the laboratory during all seasons. It is interesting to note that the greenhouse thrips is much more tolerant to tartar emetic-sucrose residues than is the citrus thrips.

The technique of testing consists of dipping oranges in the solution and, after drying for 12 hours in the laboratory, infesting each orange with 50 adult thrips. Each infested orange is placed in a suitable cage and mortality counts are made at 48-hour intervals. The percentage mortality after 7 days is used as a criterion for the effectiveness of the solution.

Distilled water solutions containing, (a) 1 per cent sucrose, (b) 1 per cent sucrose plus 1 per cent tartar emetic, (c) 1 per cent sucrose plus 1 per cent potassium antimony citrate, have been tested at pH values of 3.0, 4.0, 5.0, 6.0, 7.0 and 8.0. The pH of tartar emetic solutions was adjusted with sodium hydroxide or tartaric acid. The pH of potassium antimony citrate solutions was adjusted with sodium hydroxide or citric acid.

The pH values were determined with the Beckman pH meter. The pH of the unadjusted tartar emetic solution was 4.4. This solution remained crystal clear on standing for several days. The pH of the potassium antimony citrate solution was 4.2 and also remained crystal clear for several days. Addition of sodium hydroxide to the tartar emetic solution caused permanent clouding when a pH slightly greater than 6.0 was reached. This clouding increased progressively as the pH was increased. At a pH of 8.0, a heavy white precipitate was produced almost immediately, indicating that appreciable quantities of an insoluble material had been formed. This white precipitate was found to contain a high percentage of antimony and was probably hydrated antimony oxide, formed by the hydrolysis of the $(SbO)^+$ group. A similar condition occurred in the potassium antimony citrate solution when sodium hydroxide was added, although clear solutions persisted at a higher pH than in the case of tartar emetic. These solutions remained clear until the pH had been adjusted to a value slightly higher than 7.0, at which point slight clouding occurred. These observations illustrate the higher buffer capacity of potassium antimony citrate as compared with tartar emetic. This is further illustrated by the fact that the pH of these solutions were nearly the same in distilled water, *i.e.*, tartar emetic pH = 4.4, potassium antimony citrate pH = 4.2, whereas in a typical spray water the pH of the tartar emetic solution was 6.1 and the pH of the potassium antimony citrate solution was 4.4.

The toxicity of tartar emetic-sucrose residues was significantly affected by the pH of the spray solution. Residues from solutions at pH values of 6.0 and 7.0 were the most toxic of those tested. At lower pH values, residues were less toxic and at a pH of 8.0 they were markedly less toxic than at all other pH values tested.

The toxicity of residues from potassium antimony citrate solutions was affected by the pH to a much greater degree than in the case of tartar emetic. The highest toxicity was reached at a pH of 6.0 and 7.0. The toxicity was greatly reduced in the lower pH values. Residues from the solution of pH 3.0 were relatively nontoxic and at a pH of 8.0 they were less toxic than at values of 5.0, 6.0, and 7.0.

It is of possible significance that in typical spray water the pH of the tartar emetic solution (pH = 6.1) is within the optimum range (pH 6.0 to 7.0). It is also significant that the pH of the potassium antimony citrate solution in typical spray water (pH = 4.4) is below the optimum pH range (6.0 to 7.0). When the solutions of potassium antimony citrate were adjusted to a pH value of 6.0, their residues were practically as toxic to this insect as the residues from a solution of tartar emetic at the unadjusted pH value in typical spray water (pH 6.1). This is a possible explanation for the relatively inferior results obtained with potassium antimony citrate in control of the citrus thrips during the 1940 season.

The mortality on oranges dipped in solutions containing sucrose only was very low and did not vary significantly with respect to pH.

It is of interest that the effectiveness of these solutions increases with a rise in pH to a maximum value in the region 6.0 to 7.0. At a pH of slightly greater than 7.0, a rapid decrease in effectiveness is noted, indicating a fairly narrow and critical pH range over which these two compounds lose almost their entire toxicity.

Additional study will be necessary to determine the full significance of this principle and its application to the problem of the control of other species of insects. Further work in the laboratory and field is continuing on the subject of the role of various salts and optimum pH ranges in various spray waters as they affect the toxicity of solutions of tartar emetic and related antimony compounds.—5-24-41.

[1] Boyce, A. M., and C. O. Persing. Unpublished data on file at the Citrus Experiment Station, Univ. of California.

FIG. 1.—Five-year old apple trees at time of unfolding leaves and opening blossoms.—Left; uninfested; Right; with nearly all leaf and blossom buds eaten by *Dyslobus tanneri*.

Dyslobus tanneri Van Dyke, a Pest of Apple in the Northwest

M. A. YOTHERS, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

In April 1916 the writer's attention was called to injury to opening buds of apple trees in Yakima, Wash. Normal trees in the orchard were coming into bloom and on them new leaf buds were opening or had already burst into small leaf clusters (Fig. 1), whereas the injured trees showed neither blooms nor open buds nor leaves of any size. Examination showed that the buds had practically all been eaten off or hollowed out. In the soil at the base of the trees great numbers of weevils were found, as many as 100 to a tree, feigning death under clods close to the tree trunks. A few were hidden in curled old leaves and among small clods in the tree crotches. Since the orchard had recently been thoroughly cultivated, about the only plants present other than the trees were occasional alfalfa and dandelion plants. Weevils were found under practically every one of these plants in various parts of the orchard, and the leaves of both species had been eaten considerably.

Certain trees were severely injured by the weevils while others, of the same variety in the same orchard, were untouched. Apparently this species is somewhat gregarious, as are certain other Otiorhynchinae. Prune trees, alternating with apple trees, were undisturbed, and no weevils were found at their bases.

From 11 a.m. to 6 p.m. on the day of the examination no weevils were found out in plain sight or on the buds, but in the evening, when the trees were examined by means of a flash light, scores of weevils were at work over the trees wherever one could see from the ground. Many of them stood braced, with legs outspread, with their beaks well down inside the hollowed-out buds. They were also feeding on the alfalfa and dandelion leaves, as many as 30 on a dandelion and 75 on a small alfalfa plant. Obviously the destruction of all other plants by cultivation had concentrated the weevils on the apple trees and on the scattered remaining dandelion and alfalfa plants.

In April 1930, after an interval of 14 years, the writer collected additional individuals of this species in the Yakima district, but no record was made of

[1] In 1916, when part of these observations were made, the author was a member of the staff of Washington State College.

the circumstance of the collection. The weevils, however, were not taken on fruit trees in the collections of 1930.

Up to this time the identity of the insect had not been determined. A few years later specimens were identified by Peter C. Ting, then with the California State Department of Agriculture as *Dyslobus tanneri* Van Dyke. This species (Fig. 2) was described (Van Dyke 1933) from a single female specimen

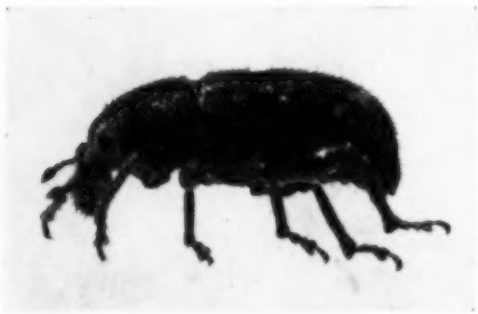


FIG. 2.—*Dyslobus tanneri* (Van Dyke) adult beetle. (×6)

taken near Salt Lake City, Utah in July 1927. Mr. Ting has indicated the distribution area of this insect to be Utah, British Columbia, Washington, Idaho, Oregon, and California as far south as Nevada County.

In May and June 1940 F. W. Carlson and the writer collected several dozen individuals of the weevil at the base of alfalfa and dandelion plants growing in an orchard and in the trash at the base of mature apple trees. Several of these confined with soil in a small tin box in the laboratory deposited eggs on the soil, or on small dead particles of grass or weeds, from May 23 to June 14. Some of the eggs hatched on June 8.

In tests from May 13 to July 6 confined weevils ate of the following kinds of leaves: Alfalfa, apple, chickweed, dandelion, elder, elm, goldenglow, lambsquarters, locust, maple, morning-glory, peach, rose, sweetclover, sweet pea, snowball, and Virginia creeper. They refused the following: Dock, grape, hollyhock, hydrangea, lilac, peony, spirea, and violet.

All known specimens of this species are females, indicating that it, like certain other species of *Dyslobus*, may be parthenogenetic.

Thus another weevil injurious to fruit trees in the Pacific Northwest is added to those previously described by the author (Yothers 1916; 1928).—4-20-41.

LITERATURE CITED

Van Dyke, Edwin C. 1933. A short review of *Dyslobus* Leconte, a genus of broad-nosed weevils of the subfamily Otiorhynchinae with descriptions of new species. Pan-Pacific Ent. **9**(1): 31–47.

Yothers, M. A. 1916. Bud weevils and other bud feeding insects of Washington. Wash. Agr. Expt. Sta. Bul. **124.**

Yothers, M. A. 1928. Observations on the snout-beetle, *Evotus naso* Lec., on apple trees at Yakima, Washington. JOUR. ECON. ENT. **21**(6): 832–6.

Dust As an Inhibiting Factor in the Reproduction of Insects

STANLEY E. FLANDERS, *University of California, Riverside*

Accumulations of comminuted earth form one of the hazards of insect life. A dusty environment is unfavorable to many species of insects. Stelle (1880) noted that road dust apparently retarded the work of the bollworm and the cotton worm for about 40 feet from the lee side of a much traveled road. In order to protect plants from the ravages of flea beetles (Halticinae), the driving of sheep over the areas infested is recommended so that the dust raised will settle on the plants (Martin 1928). Ants dislike to excavate in soil that reduces readily to dust (Wheeler 1913). It is common knowledge that mammals and birds dust themselves to rid their bodies of insect pests. As pointed out by Zacher & Kunike (1930), the lethal effect of dust increases with the aridity of the environment and the amount, adhesiveness and fineness of the dust.

The habit of insects cleaning themselves with their legs has often been observed. Mote, *et al.* (1926) called attention to the habit of certain insects of passing their legs and antennae between their mouth parts for the purpose of removing dust material. A pinch of powdered milk sugar in petri dishes containing the German cockroach, *Blatella germanica* (L.), stimulated the cleaning action. The European earwig, *Forficula auricularia* L., was stimulated likewise when confined on cabbage plants dusted with milk sugar. The milk sugar dust was lethal to both of these species.

Inert dusts are lethal in effect since they bring about either the starvation or the desiccation of the insect.

Dusts may form a mechanical barrier to the food supply (Driggers 1928), prevent the movement of legs and mouth parts (Germar 1936) or clog the digestive system (Richardson & Glover 1932; Boyce 1934).

At humidities below 70 per cent, dusts facilitate the desiccation of insects either by modifying the permeability of the cuticle (Hockenyos 1933), by exposing the permeable intersegmental membranes (Germar 1936), or by increasing the evaporating surface of the body (Zacher & Kunike, 1930; Chiu 1939).

Chiu found that bentonite, a clay with marked water-absorptive powers, was most effective against the bean weevil, *Acanthoscelides obtectus* (Say). Germar found that a siliceous powder made up of finely ground quartz sand, which is not hygroscopic, was most effective against the grain weevil *Sitophilus granaria* (L.). This material becomes packed in the intersegmental spaces until the insect moves with difficulty. The capillarity of the packed dust facilitates the removal of water from the insect. Kennedy (1927) has pointed out that to an animal as small as an insect, which has such a large surface dissipating moisture in proportion to the small volume containing it, the matter of moisture loss is serious.

The *sensitiveness* of an insect when its minimum limit of surrounding humidity is approached is a most outstanding adaptation. The fatal limit of desiccation, however, varies for different species. Consequently species exhibit a variation in susceptibility to desiccating dusts. Kennedy states that the many small insects that manage to live in comparatively exposed and dry situations are usually sucking insects (hemipterous), which can supply

moisture, dissipated in the low humidity, by the constant intake of plant or animal juices. He noted that "This applies especially to the numerous small Homoptera which are also well protected by a relatively thick chitinous body wall." The permeability of the cuticle of insects to water is as varied as is its rigidity and capacity for stretching. The secretions of certain of the dermal glands, particularly those secreting wax, must play an important part in modifying the permeability of the cuticle (Wigglesworth 1939).

The Homoptera and Hymenoptera represent the extremes in susceptibility to dusts, a difference due largely to differences in habit. The susceptibility of the Hymenoptera to dust is correlated with specialized structures for removing dust particles from their food or from the surface of their bodies.

In most species the adult hymenopteron feeds on liquid foods. A fringe of setae (oral pectin) projecting over the slit-like mouth serves to strain out of its food particles of dust and other solid matter. Such material is then transferred to the "gnathal pouch" located below the mouth. This pouch may also receive the dust particles removed from the antennae by the forelegs.

The strigil, or antennae-cleaning device, consists of a modified spur on the fore tibia, which fits against a pectinated semicircular pit on the first tarsal joint. The antennae are cleaned when passed between these organs. The debris on the antenna-cleaner is then transferred to the gnathal pouch by passing the forelegs through the mouth parts. When necessary, the forelegs may assist in emptying the pouch since, as Duncan (1939) has pointed out in the case of the wasps, there are no muscles attached to it.

In the ants, the contents of the gnathal pouch are eventually thrown out as a little pellet which preserves the form of the chamber in which it was moulded. Such pellets are often seen scattered about the floor of artificial nests after the ants have been fed on starchy substances or after their bodies have been dusted with plaster of paris (Wheeler 1913).

The hind legs constitute a wing-cleaning device, because of the brush of short hairs on the lower surface of the hind tibia.

The parasitic hymenopteron may pass the debris, removed from the antennae, mouth parts and other parts of the body, backward by means of each pair of legs. The debris is then cast off by the hind legs.

When small species of parasitic Hymenoptera, such as *Trichogramma*, come in contact with an excessive amount of dust, their movements lack coordination and they "wallow" helplessly.

A significant situation is known to occur with respect to the codling moth. Driggers (1928)observed that on plants dusted with talc or with mica, over 90 per cent of newly hatched larvae died before they reached a point of entry. He considered the lethal effect to be physical rather than chemical. Callenbach (1940), however, reported excessive codling moth injury in areas bordering upon dusty highways and orchard roads. Experimental data showed "that codling moth injury is uniformly greater the more severe the dust conditions, and that the dust had a tendency to build up on deposits of spray residues." The lethal effect of the dust on the natural enemies of the egg and the newly hatched larva of the codling moth may be relatively much greater than on the codling moth.

The parasites of pests not only may be more susceptible to dusts but they may be more uniformly affected than their hosts since they are largely hymenopterous or dipterous and consequently are more uniform in structure and in their feeding habits.

Folsom (1927) observed that while calcium arsenate had little, if any, lethal effect on the cotton aphis or its predatory enemies, it destroyed the hymenopterous parasites. The same effect was obtained when inert dusts were applied to the plants. Cornstarch killed *Aphidius testaceipes* Cresson in 65 minutes, and calcium carbonate in 66 minutes. *Pachyneuron siphonophorae* (Ashm.) was killed by cornstarch in 6 to 12 hours, and by calcium carbonate in 68 minutes. The lethal effect on the parasites was determined by the amount of dust on the plants for *heavy* infestations of aphis did not result from the commercial number of applications but only from *excessive* applications.

As a rule, inert dusts, when used as carriers of volatile poisons, are not applied in amounts sufficient to affect insect parasites. Morrill (1921) found that nicotine-ipmregnated dusts did not destroy *Aphidius testaceipes* when used against the melon aphis. In fact the aphids that survived the poison because of their location in curled leaves then received the concentrated attack of the parasites. It is in this respect that volatile poisons are superior to non-volatile materials, as pointed out by Clausen (1936).

Chemically active dusts, however, when used as contact poisons may be very destructive to hymenopterous and dipterous parasites, and even to predators.—4-28-41.

LITERATURE CITED

Boyce, A. M. 1934. Bionomics of the walnut husk fly, *Rhagoletis completa*. Hilgardia **8**: 361–579.

Callenbach, John A. 1940. Influence of road dust upon codling moth control. JOUR. ECON. ENT. **33**: 803–7.

Chiu, Shin Foon. 1939. Toxicity studies of so-called "inert" materials with the bean weevil, *Acanthoscelides obtectus* (Say). JOUR. ECON. ENT. **32**: 240–8.

Clausen, C. P. 1936. Insect parasitism and biological control. Ann. Ent. Soc. Amer. **29**: 201–23.

Driggers, Byrley F. 1928. Talc and mica dusts as a control for lepidopterous larvae. JOUR. ECON. ENT. **21**: 938–9.

Duncan, Carl D. 1939. A contribution to the biology of North American vespine wasps. Stan. Univ. Pub. Biol. Sc. **8**: 1–272.

Folsom, J. W. 1927. Calcium arsenate as a cause of aphis infestation. JOUR. ECON. ENT. **20**: 840–3.

Germar, B. 1936. Versuche zur Bekämpfung des Kornkafers mit Staubmitteln. Zeit. Angew. Ent. **22**: 603–30.

Hockenyos, George L. 1933. Effect of dusts on the oriental roach. JOUR. ECON. ENT. **26**: 792–4.

Kennedy, C. H. 1927. Some non-nervous factors that condition the sensitivity of insects to moisture, temperature, light and colors. Ann. Ent. Soc. Amer. **20**: 87–106.

Martin, Hubert. 1928. The scientific principles of plant protection. Edward Arnold and Company, London.

Morrill, A. W. 1921. Notes on the use of nicotine dusts. JOUR. ECON. ENT. **14**: 394–400.

Mote, Don C., Joseph Wilcox and Earl G. Davis, 1926. The natural "cleaning up" habit of insects. JOUR. ECON. ENT. **19**: 745–8.

Richardson, C. H., and L. H. Glover. 1932. Some effects of "inert" and toxic substances upon the twelve-spotted cucumber beetle, *Diabrotica duodecimpunctata* (F.) JOUR. ECON. ENT. **25**: 1176–81.

Stelle, J. P. 1880. Road dust vs. cottonworms. Amer. Entom. **3**: 251–2.

Wheeler, William Morton. 1913. Ants, their structure, development and behavior. Columbia Univ. Biol. Series **9**: 1–663.

Wigglesworth, V. B. 1939. The principles of insect physiology. E. P. Dutton and Company, New York.

Zacher, F., and G. Kunike. 1930. Untersuchungen über die insektizide Wirking von Oxyden und Karbonaten. Arb. Biol. Reichsanst. **18**: 201–31.

A Maggot Attacking Carnation Shoots

CHARLES F. DOUCETTE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

An unusual injury to young carnation plants (*Dianthus caryophyllus* L.) at Portland, Ore., was called to the attention of the Sumner, Wash., laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in the spring of 1936. Dipterous larvae feeding in the young developing shoots were destroying these growth centers (Fig. 1). The injury was extensive at one location in the east Portland area, where it had been observed by a grower in 1933 and each year since. A few similarly injured plants were also found at two nearby locations in 1936. Adult flies reared from collected larvae and pupae were determined and described by Hall (1937) as a new species, *Hylemya abdena*. Except in two instances, where young plants inside a greenhouse near a door were attacked, the injury was noted only on young plants being grown outside preliminary to transplanting into greenhouse benches for flower production.

At Portland the young carnation plants are ordinarily transplanted outside in the middle of April or later, after danger from frost is past. Injury by this insect first becomes noticeable early in May and the larvae become full grown late in May or early in June. Most of them pupate in the soil below the plant, but occasionally a puparium may be found in a plant tip. Adults emerge from these pupae early in and in the middle of June. Surprisingly, instead of an expected heavy infestation following this period of adult emergence, only a very few larvae representing a new generation could be located in the carnation plants. Nothing has been learned as yet concerning the method of overwintering or of hosts that might serve to carry the insect through the season when carnation plants are not available.

The injury developing from the spring attack results in effect in a biological pruning or "pinching back." Following the cessation of feeding new growths develop on most of the plants, and, since the succeeding generations of the fly do not attack these new growths to any extent, the plant development proceeds without further difficulty. However, the failure of many of the plants to assume satisfactory or desirable form is of considerable importance to the grower, as he considers it necessary to discard such plants.

FIG. 1.—Developing shoot of carnation plant sectioned to reveal nature and extent of feeding by *Hylemya abdena* larva.

European literature records several species of *Hylemya* attacking carnations. The most important apparently is *H. brunnescens* Zett., which is primarily a stem-feeding form, most of the injury occurring below the soil level. This species is commonly called the carnation maggot in England. It has been reported in British Columbia by Spencer (1933). Spencer also described injury to "leafheads" of carnation which seems very similar to that observed by the writer as being produced by *H. abdena*, but unfortunately he did not rear adults from larvae specifically in the plant tips. Therefore positive determination of the species involved in this type of attack was not obtained. *H. cardui* Meig. and *H. fugax* Meig. are mentioned as attacking carnations in Europe, but these do not appear to have been studied so extensively as *H. brunnescens* and perhaps have not caused serious injury. Since the taxonomy of the genus has been in a rather confused condition, it is uncertain just what form is under consideration in many of the accounts.—5-1-41.

LITERATURE CITED

Hall, David G. 1937. New muscoid flies (Diptera) in the United States National Museum. U. S. Natl. Mus. Proc. **84**(3011): 201–16.

Spencer, G. J. 1933. The identity of the carnation maggots of British Columbia. Ent. Soc. Brit. Columbia, Proc. **30**: 21–2.

Control of Tulip Aphids on Southern Iris

L. GORDON UTTER, *Brooklyn Botanic Garden*

In late October 1938, field-grown plants of the southern iris, *Iris fulva* Ker-Gawler, *I. brevicaulis* Raf., *I. giganticaerulea* Small, and various hybrids, were dug, potted, and placed in the greenhouse for use in hybridization. Heavy infestations of the tulip aphid, *Anuraphis tulipae* Fonsc., later appeared on most of these plants. Well developed colonies of the aphids were found within the basal part of the leaf sheaths and, in severe cases, over considerable areas of the leaf surface. Injury consisted of a progressive yellowing of the infested leaves, followed by their death. Plants which had several shoots infested exhibited poor vigor. At blooming time, later in the season, the flower stalks and flower bracts usually were infested with the aphids. Infestations within the flower bracts and stalk leaves remained obscure until the aphids became so numerous that many were crowded to the outside. Young and ripening seed pods also were injured. Although the tulip aphid is often found on southern iris in the field, its damage appears to be negligible. However, it may prove serious on these same plants under greenhouse conditions.

Tests were made during November 1938, with infested plants placed in a paper-covered frame chamber and fumigated for one hour with *Nicofume* tobacco powder (containing not less than 14 per cent of nicotine) and *Cyanogas-G fumigant*, (containing not less than 42 per cent of calcium cyanide). Poor control was obtained with the tobacco powder at dosages of either 20 or 30 ounces per 1,000 cu. ft. of space and slight burning of the iris foliage occurred at the higher dosage. Fumigations for one hour with *Cyanogas* at dosages of either 2 or 3 ounces per 1,000 cu. ft. of space gave excellent control of the aphids without injuring the iris. The results with *Cyanogas* were confirmed by three fumigations of the entire greenhouse at approximately two-week intervals. At the end of each fumigation period, the greenhouse was thoroughly aired.

In 1939 and 1940, five and four fumigations, respectively, with *Cyanogas* at the 2 ounce rate, were made at approximately biweekly intervals from October to January on about 350 pots of southern iris. A buffer dosage of *Cyanogas* (.33 ounce to 1000 cu. ft. of space) was released in a lean-to greenhouse attached to the main house in which the iris plants were growing, to prevent excess diffusion and lowering of the gas concentration around the iris plants being fumigated. Careful inspections of the plants afterward indicated that a high degree of control was obtained, but the survival of an occasional aphid within the leaf sheaths required the continuance of such measures.

The growing of cereals in the same house with the iris prevented further fumigations, since they were injured by the *Cyanogas*. However, by spraying at biweekly intervals with a combination of nicotine sulfate (40 per cent) at 1 to 400 plus *Grasselli Spreader Sticker* at 1 to 1,000, it has been possible to maintain the iris plants rather free from increased populations and aphid-injury following the fumigation period. The nicotine sprays readily killed the exposed aphids but did not penetrate into the leaf sheaths as well as the fumigant. Complete kill of the aphids, with either spray or fumigant, was difficult to obtain because of the protection provided by the leaf sheaths.—2-11-41.

Concentrations of Derris Sprays Effective on the Imported Cabbage Worm

LOUIS PYENSON, *State Institite of Applied Agriculture, Farmingdale, N. Y.*, and ROGER W. ROTH, *Atlas Powder Co.*

The present recommendation for the control of the imported cabbage worm, *Pieris rapae* (L), for those who prefer to use a derris spray instead of a dust, is 4 lbs. of derris (4 per cent rotenone) to 100 gals. of water plus a suitable spreader and sticker. Tests made by the writers during the summer of 1940 indicate that much less derris can be used in the spray with equal effectiveness.

The experiments were made in a heavily infested field of cabbages which were just beginning to cup their inner leaves. The plots consisted of approximately 125 cabbages with from one to eight larvae per plant. The majority of the larvae were about half-grown. The sprays were applied with a knapsack sprayer and the dusts with a knapsack bellows duster during the period of one week in the latter part of July. The weather during this period was mostly clear and hot. Mortality counts were made 24 hours after each application on all the cabbages of each plot. The larvae observed in each plot totaled nearly 200 in most cases. The spray was applied thoroughly to the center of the plants where most of the larvae were feeding.

The data in table 1 show that as little as 1 pound of derris per 100 gals. of water was effective against the larvae. No significant differences in kill resulted from the use of different spreaders, although *NNO*[1] was the only spreader that gave good wetting of the leaves.

Table 1.—A comparison of the effectiveness of different spray concentrations of derris with different spreading agents against the imported cabbage worm.

	PER CENT KILL			
Pounds of Derris per 100 gal. water	4	2	1	0.5
Derris[1]—*NNO*[2]	92	96	95	53
Derris[1]—*Grasselli Spreader*[2]	91	95	89	55
Derris[1]—Fish Oil Soap[2]	87	93	88	50
Derris[1]—Skim Milk Powder[2]	—	—	89	—
Check	0	0	0	0

[1] Ground derris root, 4 per cent rotenone.
[2] *NNO* (Technical Mannitan Monolaurate—Atlas Powder Co.) 1-1,600; *Grasselli Spreader*, 1-1,000; fish oil soap, 1:800; skimmilk powder, 3 lbs. to 100 gals.

The results with *NNOR*[1] (*NNO*—1 per cent Rotenone) and *NNOP*[1] (*NNO*—1.1 or 2.2 per cent pyrethrins) sprays in table 2 indicate that they are not as effective as derris sprays on the larvae at economical dilutions. However it was observed in other experiments that *NNOR* and *NNOP* at 1 to 800 dilutions were effective against aphids and thrips on the plants; and that *NNOR* at 1 to 400 killed an appreciable number of the eggs of the insect.

[1] *NNO*, *NNOR*, and *NNOP* are trade marks of the Atlas Powder Co., Wilmington, Del. The samples used were supplied by this company.

Field experiments with power sprayers on several Long Island farms indicated that *NNOP* 2.2 per cent diluted 1 to 600 is effective against cabbage loopers as well as the imported cabbage worm, if good spray coverage is obtained.

Table 2.—A comparison of the effectiveness of two new sprays against the imported cabbage worm.

	Per Cent Kill		
Dilution	1–600	1–800	1–1,000
NNOR	81	76	69
NNOP 1.1%	89	61	—
NNOP 2.2%	—	72	69
Check	0	0	0

Two plots dusted with a .75 per cent rotenone dust (made from derris, 4 per cent rotenone) gave a 96 per cent and 93 per cent kill respectively; while a plot dusted with pyrethrum (1 lb. *Dry Pyrocide* diluted with 9 lbs. talc) gave 89 per cent kill.

The experiments show that the results obtained with derris sprays of one-fourth the strength recommended compare favorably with those obtained with the derris and pyrethrum dusts.—4-7-28.

Field Trials with Two New Contact Insecticides

ROGER W. ROTH, *Atlas Powder Co.*, and LOUIS PYENSON, *State Institute of Applied Agriculture, Farmingdale, N. Y.*

Considerable promise in the control of some insect pests has been shown by two new contact insecticides in field experiments conducted in the summer of 1940 by the writers.

Technical mannitan monolaurate, *NNO*,[1] is harmless to man when used as recommended and has exceptional spreading and wetting properties. *NNOR*[1] is technical mannitan monolaurate, 97.2 to 96.4 per cent; rotenone, 1 per cent; and other derris extractives, 1.8 to 2.6 per cent. *NNOP*[1] is technical mannitan monolaurate with 2.2 per cent pyrethrins in it. *NNOR* has recently been used as a greenhouse spray for red mites on roses.

Tests were made to determine the effectiveness of *NNO*, *NNOR*, and *NNOP* on the green apple aphids, *Aphis pomi* DeG. In each treatment two trees were sprayed with a knapsack sprayer, and a heavily populated twig on each tree was bagged with a paper bag as soon as the spray had dried. Mortality counts on the bagged twigs were made 24 hours after the applications.

Table 1.—A comparison of the effectiveness of different sprays and spray concentrations against the green apple aphid.

	Per Cent Kill			
Dilution	1:600	1:800	1:1,000	1:1,200
NNO	49	—	—	—
NNOR	99	94	89	79
NNOR	—	92	—	—
NNOP	—	82	80	—
Check	2 to 3 per cent mortality			

[1] Manufactured by the Atlas Powder Co. of Wilmington, Del.—*NNO*, *NNOR*, and *NNOP*—Trademarks of Atlas Powder Co.

The data in table 1 indicate that *NNO* alone has considerable toxicity to the aphids, and that *NNOR* gives satisfactory control at high dilutions. Excellent control of aphids was also obtained with *NNOR* diluted 1 to 800 on a heavily infested black gum tree and on heavily infested cucumber vines in the greenhouse. No injury was apparent from any of the spray applications.

Some promising results were obtained with the use of *NNOP* in control of corn earworm, *Heliothis armigera* (Hbn.) (Table 2). The various dilutions were injected into the tips of the ears with a *Plews Pistol Oiler*, which ejected about .75 cc. of liquid at each pull of the trigger. All treatments were timed according to directions given by Carruth (1940).

Table 2.—The effectiveness of *NNOP* at different dilutions as compared with other treatments recommended for corn earworm control.

	Date	Per Cent Ears Infested After Treatment[1]			
	Dilution—	1:10	1:25	1:50	1:100
NNOP	July 30	6.8	15.4	7.6	10.5
	August 5	5.3	10.6	14.8	8.0
Mineral oil[2]	July 30		3.2		
2% dichlorethyl ether	August 5				12.0
Corntrol[3]	July 30		5.6		
	August 5				5.3
Clipped ears	August 5				10.0
Check (untreated)	July 30		31.4–24.5		
	August 5				41.2

[1] All ears injured by larvae or containing live larvae.
[2] White mineral oil, *Fractol A*; obtained from Stanco Distributors, Inc., N. Y. C.
[3] Mineral oil containing pyrethrins, prepared by Stanco Distributors, Inc., N. Y. C.

Approximately 60 ears were examined in each plot treated on July 30; while from 100 to 200 ears were examined in each plot treated August 5. Although the infestations in the check plots were light and the results of the treatments variable, *NNOP* dilutions produced results comparable with the treatments recommended by Carruth (1940) with less injury to the ears. Some silk rot appeared in about 10 per cent of the ears treated with *NNOP*. In view of these results *NNOP* treatments seem worthy of further investigation.

In further trials dilutions of *NNOR* as high as 1:1,200 gave 86 per cent mortality of potato flea beetles on egg plants and a dilution of 1:800 gave a 97 per cent kill of thrips on young rhododendrons.

NNOR, 1:800, applied to turf with a sprinkling can at the rate of two gallons per square yard gave 89 per cent mortality of the hairy chinch bug while derris (4 per cent rotenone) at 2 lbs. per 100 gals. of water plus *NNO* 1:1,600 gave 92.5 per cent mortality. Small local infestations may be controlled effectively with either of these spray solutions.

The field trials indicated that *NNOR* will give good control of certain aphids, thrips, the potato flea beetle, and the hairy chinch bug; and that *NNOP* shows promise in corn earworm control. No foliage injury was observed.—4-7-41.

Literature Cited

Carruth, L. A. 1940. The corn earworm and its control, N. Y. Agr. Expt. Sta. Circ. 190.

Effect on Amaryllis Bulbs of Hot Water and Cyanide Used in Control of Bulb Fly Larvae

F. S. BLANTON, *U. S. Department of Agriculture Bureau of Entomology and Plant Quarantine*

In preliminary tests on Long Island, N. Y., in the fall of 1938 several hundred amaryllis bulbs, *Lycoris squamigera* Maxim., were either immersed in hot water or subjected to cyanide fumigation in order to kill the larvae of the bulb fly, *Merodon equestris* (F.). The bulbs were then planted in the field and 2 years later were dug and examined to determine the effect of the treatments on their growth.

Table 1.—Tolerance of amaryllis bulbs to hot water and sodium cyanide for the control of *Merodon equestris*.

Treatment	Number of Bulbs	Diameter, Inches	Total Weight, Grams	Average Weight, Grams	Change in Weight After 2 Years, Per Cent
Hot water	780	.25–.5	5,612	7	+35
	50	.75–1	1,007	20	+68
	130	1–5	21,433	165	−13
Sodium cyanide	60	.75–5	10,884	181	−53

The hot-water treatment consisted of immersing the bulbs in water held at a temperature of 110 degrees F. for 1 hour, exclusive of the "approach period," or the time required to heat the center of the bulb to 110 degrees. The approach period was 25 minutes for the smaller bulbs and 1 hour and 25 minutes for the larger bulbs. This treatment was employed for bulbs of three sizes. The very large bulbs were heavily infested with larvae, whereas the small bulbs were practically free from the insects.

Only large bulbs were fumigated, and these were subjected to sodium cyanide at the rate of 7 ounces to 100 cubic feet for a period of 4 hours. The fumigation chamber was equipped with a small electric fan, which kept the air circulated.

Most of the large bulbs were so heavily infested with larvae of *Merodon equestris* that it was thought advisable to treat all of them rather than to leave some untreated as checks.

All treatments were conducted on October 21. At that time the bulbs were not thoroughly dormant, having been dug only 10 days previously. The bulbs were weighed and planted in the field 3 days after treatment, in 1938, and were dug in July 1940. During adult-fly activity, from May 10 to July 1 on Long Island, the bulbs were screened with cheesecloth to prevent reinfestation. The cages were examined during the season of fly activity in 1939 and 1940, and no flies were observed. When the bulbs were examined after harvest, none were found to be infested.

A number of the small bulbs, which had received the hot-water treatment, did not grow, apparently lying dormant during the entire 2-year period, while others presumably rotted. No doubt some of this loss was due to the lack of hardiness of amaryllis, and plaiting in the field may have contributed to the dormancy of the small bulbs. Bulb yields 2 years after treatment are shown in table 1.

It is not definitely known why the two lots of large bulbs lost weight. Since these bulbs when harvested were free from infestation, but had divided into numerous bulblets, it is possible that this enormous production of bulbs caused some of the loss. The average increase in number of bulbs was approximately 20 times, and 1 bulb produced 50 bulblets. The normal increase of this size bulb, after 2 years' growth, when not infested or injured, would not be more than three or four times the number planted. When large bulbs begin to divide, there is seldom any increase in weight, the stored food being transferred from the mother bulb to the bulblets.

The loss in weight may have been due to the fact that portions of the mother bulbs had been consumed by the fly larvae. The increase in the number of bulbs was possibly due to mechanical injury to the basal plate of the bulbs by larval feeding. In the production of amaryllis bulbs the basal plate is sometimes injured with a knife in order to stimulate bulb production.

There is a possibility that the fly may be beneficial as a mechanical stimulant for increased production of bulbs, but it is not known whether the feeding of the larvae will offset these benefits.

Precaution should be taken against reinfestation after treatment in order to protect the bulblets. This can be accomplished by screening the bulbs with cheesecloth or other material.—5-15-41.

Type of Wood Preferred by Coleoptera Commonly Found in Decadent Parts of Living Elm Trees

W. C. BAKER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

In the control of the Dutch elm disease the practice of sanitating areas by pruning dead and dying parts from living elm trees has been applied for the purpose of reducing the active brood of bark beetle and other coleopterous larvae and eliminating material suitable for their development. To know better how much insect material could be removed by such work and what branches must be removed to make the work most effective, numerous examinations were made of pruned material to determine the size and condition of the branches in which common elm-bark-inhabiting larvae develop. These examinations were made throughout the year on limbs 1 to 14 inches in diameter pruned from a total of more than 600 elm trees. The pruning work was done by the Dutch elm disease eradication unit of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in Connecticut, New York, New Jersey, and Pennsylvania during the period 1937–39. The bark beetle and certain other coleopterous larvae found developing in the bark and wood were identified, and the type of branch in which they were found was noted.

The numerous examinations of the dead and dying parts indicated that the more common species of Coleoptera attacking these parts were the two elm bark beetles *Scolytus multistriatus* Marsh. and *Hylurgopinus rufipes* (Eich.); certain cerambycids, such as *Saperda tridentata* Oliv. and *Neoclytus acuminatus* (F.); the curculionids *Magdalis armicollis* (Say) and *M. barbita* (Say); the buprestid *Anthaxia viridifrons* Gory; and certain saprophagous and carnivorous beetles.

These examinations also showed that the species of insect attacking a branch and the degree of its attack were dependent on the diameter and the condition of the material. Thus, those branches above 3 inches in diameter that appeared to have died since the preceding early autumn were attacked in the spring by the bark beetle adults emerging from the overwintering broods. Similar-sized branches were attacked by the second generation of *Scolytus multistriatus* when such branches had died during the late spring or summer. Branches under 3 inches in diameter that were almost dead or appeared to have just died were attacked by the two species of *Magdalis*. Limbs that had been dead for one to several months were infested by other beetles, such as the synchroid *Synchroa punctata* Newm., the cucujid *Cucujus clavipes* F., and the clerid *Enoclerus quadriguttatus* (Oliv.).

The smaller European elm bark beetle, *Scolytus multistriatus*, is considered more important than the native elm bark beetle, *Hylurgopinus rufipes*, in disseminating the Dutch elm disease fungus, *Ceratostomella ulmi* Buisman. In pruned material egg and larval galleries of *S. multistriatus* were observed in branches upward from one-half inch in diameter. However, the pruned branches in which this insect was found most commonly were 3 to 4 inches in diameter, the degree of infestation decreasing gradually as the diameter increased or decreased.

In the same pruned material *Hylurgopinus rufipes* was found to prefer the thicker-barked branches. Elm limbs 6 inches in diameter were found to have the highest number of *H. rufipes* larvae per square foot of bark area. These larvae were also found in all pruned material above 3 inches in diameter.

In the pruned plots in Pennsylvania examination of wood from the 370 trees revealed that 91.7 per cent of the active bark beetle infestation had been removed by cutting out dead and dying branches down to 3 inches in diameter, whereas 98.7 per cent had been removed by cutting out such branches down to 2 inches in diameter.

Of the remaining elm insects the two species of *Magdalis* and the cerambycids appeared to be most numerous. These curculionids and cerambycids preferred to deposit their eggs in branches that had recently died or were very low in vitality. Occasionally a larva of one of these groups was found completing its development in a live branch of apparently low vitality. In such an instance the larva had been confined to a small area and had killed the inner bark as it fed. Many times the small cerambycid larvae were found developing in the bark and not scoring the xylem until they had become medium-sized.

The branches most favored by *Magdalis* were those of the smaller diameters. The 1-inch branches had the greatest number of larval mines per square foot, and as the diameter increased the number of larvae per square foot gradually decreased.

The diameter range in which the greatest number of cerambycids were found was between 6 and 8 inches with a steady and gradual decrease as the diameter increased or decreased.

In general very few buprestid larvae were found in dead and dying limbs. In a few instances, however, numerous larvae of *Anthaxia viridifrons* were found in 2- and 3-inch diameter branches, but other buprestid larvae, such as those of *Chrysobothris femorata* Oliv., were very seldom found.

Synchroa punctata and *Cucujus clavipes* were usually found in branches that had a diameter of 5 or more inches and that had been dead for some time. *Enoclerus quadriguttatus* was found more commonly in branches of smaller diameter in which larvae of smaller species were present.—4-20-41.

Variations in the Composition of Paris Green

R. H. CARTER and C. M. SMITH, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

It has been known for a long time that paris green is an acetoarsenate of copper, for which the formula $Cu(C_2H_3O_2)_2 \cdot 3Cu(AsO_2)_2$ has been accepted. It is also recognized that authentic commercial samples practically never contain so much As_2O_3 as the 58.55 per cent which this formula indicates, although the departures from that figure are generally not serious. Fisher and Bailey (1937) record the examination of 25 samples of paris green in which the As_2O_3 content ranged only between 53.15 and 57.81 per cent, with an average of 56.2 per cent. Dearborn (1937) collected samples of the nine brands of paris green available on the American market in 1936, and found their arsenic trioxide content to lie between 56.1 and 57.3 per cent, and to average 56.86 per cent, while the cupric oxide content, theoretically 31.4 per cent, ranged from 30.0 to 31.1 per cent.

During 1939 and 1940, however, there came to the writers' attention five samples of materials sold as paris green which departed from the accepted composition much further than this. These samples had the following composition:

	I.D. 4452	*I.D. 4512*	*I.D. 4574*	*I.D. 4576*	*I.D. 4618*
Cupric oxide, CuO	27.4	31.5	—	—	28.2
Arsenic trioxide, As_2O_3	68.5	48.0	35.4	51.4	69.4
Arsenic pentoxide, As_2O_5	1.2	8.5	39.5	—	0.3
Acetic anhydride, $(C_2H_3O)_2O$	0.4	8.8	0.06	2.5	0.1
Water-soluble As_2O_3 (A.O.A.C. Method)	1.5	—	0.4	10.9	0.5

At least two of these samples contained appreciable quantities of pentavalent arsenic, whereas normal paris green contains only the trivalent form. In the case of I.D. 4512 it is possible that the product had been subjected to the action of alkaline media, which are known to permit oxidation of as much as one-third of the trivalent arsenic by the divalent copper and thereby to render soluble a part of the acetate. If the supernatant liquid were drawn off, some of the acetate would be lost. This could account for the fact that the amount of acetic anhydride present in this sample (8.8 per cent) is less than the theoretical (10.1 per cent). Three of the samples contain practically no acetic anhydride, an indication that they contain no paris green whatever. In samples I.D. 4452 and I.D. 4618 the arsenic and copper contents suggest the copper metaarsenite monohydrate, $Cu(AsO_2)_2 \cdot H_2O$, suggested by Avery (1906). No definite explanation can be given for the

high content of As_2O_5 in sample I.D. 4574. It can only be pointed out that the total arsenic content is almost right for the copper arsenite just mentioned, and that this sample also may have been permitted to undergo internal oxidation and reduction.

In conclusion, entomologists are warned that they may be using as paris green preparations that are really copper metaarsenite, or even indefinite mixtures of copper arsenite and arsenate. The products in themselves may be satisfactory or even superior insecticides, but results obtained with them should not be ascribed to paris green.—4-18-41.

LITERATURE CITED

Avery, S. 1906. The constitution of paris green and its homologues. Jour. Amer. Chem. Soc. **28:** 1155–64.

Dearborn, F. E. 1937. Composition of paris greens manufactured during 1936. JOUR. ECON. ENT. **30:** 804.

Fisher, H. J., and E. M. Bailey. 1937. The composition of some commercial insecticides, fungicides, bactericides, rodenticides and weed killers. Conn. Agr. Expt. Sta. Bul. **398.**

An Unusual Infestation of Cabbage Aphids, *Aphis brassicae* L.

ROY E. CAMPBELL, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Late in July 1940 a field of Danish Ball Head Short Stem cabbage was observed near San Juan Capistrano, Calif., which had an infestation of cabbage aphids of an unusual nature. The cabbage was well advanced in growth, with some heads already 5 inches in diameter. The general appearance of the field was excellent, and from outward appearances no damage was apparent. (Fig. 1) However, a closer examination by turning back the outer leaves of the heads revealed a heavy infestation of aphids. In fact, when a layer of leaves was stripped back, the underneath layer was a solid mass of aphids, together with numerous syrphid larvae and other predaceous enemies (fig. 2). The owner reports that the aphids started early in the seed beds, being found deep in the heart or center of the seedlings. As the plants grew, the aphids continued to develop within the plants, few being exposed on the outer leaves.

FIG. 1.—General view of infested cabbage field, showing apparently healthy appearance.

FIG. 2.—Infested cabbage, with leaves stripped back from the head, showing mass of aphids inside.

The owner dusted the cabbage with nicotine dust four times during its growth, but since the locality was subject to considerable wind there was little good dusting weather. This resulted in delays, giving the aphids an opportunity to develop, and the owner never completely caught up on his dusting operations. He then tried spraying, using a power outfit and a heavy dosage. But the spray failed to penetrate into the infested layers. Finally, he had workmen strip back these infested layers and treated the cabbage again. This stopped the infestation, but the remaining cabbage heads were so small that the field was almost a total loss.—4-30-41.

The Ridging of Citrus Fruits As Influenced by Fumigation of Citrus Trees with HCN

DAVID L. LINDGREN and W. B. SINCLAIR, *University of California, Riverside*

Growers and field men have often observed the so-called "coxcombing" or ridging of citrus fruits but have been unable to trace the cause. Recently it has been demonstrated that when citrus trees are fumigated with HCN while the fruit is in the bud stage of development, ridging may develop. This condition is characterized by excessive ridges of growth over the surface of the fruit, in many instances resembling that of a cock's comb. In some cases it may appear as a smooth ridge. The severity varies considerably in amount and intensity. The ridges may extend to any length from the calyx to stylar ends of the fruits. They may also appear as irregular ridges over the entire surface of the fruit.

For the past year the occurrence of this phenomenon has been observed and studied in Valencia and Navel oranges, grapefruits and for the past several years on lemons.

During the last year the writers have had exceptional opportunities to observe this phenomenon under field conditions in several groves. Extensive counts have shown from 22 to 40 per cent coxcombing or ridging of fruit from February treated trees, whereas only 0.1 to 0.2 per cent ridging was found on trees receiving no fumigation or receiving fumigation in November or December. Further work is being prosecuted to determine the various factors contributing to the causes of ridging in citrus fruits and will be published elsewhere.—3-25-41.

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 34 June, 1941 No. 3

The Permanent Fund

ACCORDING to the last report of the Secretary and Business Manager, the Association had, in its permanent fund, on November 15, 1940, the sum of $23,511.42. This amount included income, from the fund, of $679.54. As it will be a great many years before the permanent fund will be large enough to yield a respectable income might it not be desirable, in the meantime, to borrow part of this fund and to use it in publishing, from time to time, worthwhile texts on the science of economic entomology?

According to Article 1, Section 2 of the constitution, the objectives of the Association are "(1) to promote the study and to advance the science of entomology; and (2) to publish the JOURNAL OF ECONOMIC ENTOMOLOGY and other entomological publications." The Association is fulfilling these objectives in a creditable manner, up to a certain point, by the publication of the JOURNAL and of the various Indices of American Economic Entomology. Why not go a step further and sponsor the publication of a limited number of manuscripts that meet certain high standards and that are likely to advance the science? Our literature is voluminous and widely scattered. Critical reviews and summaries are needed. The Association could, if it were so disposed, arrange to have certain phases of the field covered by specialists who could be assured of publication when their work was finished. I am not suggesting that the Association become a commercial publishing house for entomological texts, and I realize that additional activities require additional services; also that there is some danger of not being able to reimburse the fund if mistakes are made in selecting manuscripts. However, additional work in itself should not be a deterrent and the financial risks are not extraordinary. Certain books might be sold by advance subscriptions. Without proposing any detailed plan, it appears that by increasing its publication activities along planned lines, the Association can advance economic entomology and the interests of its membership which, after all, are its primary purposes. The accumulation of interest at niggardly rates is a much less worthwhile activity.

H. B. W.

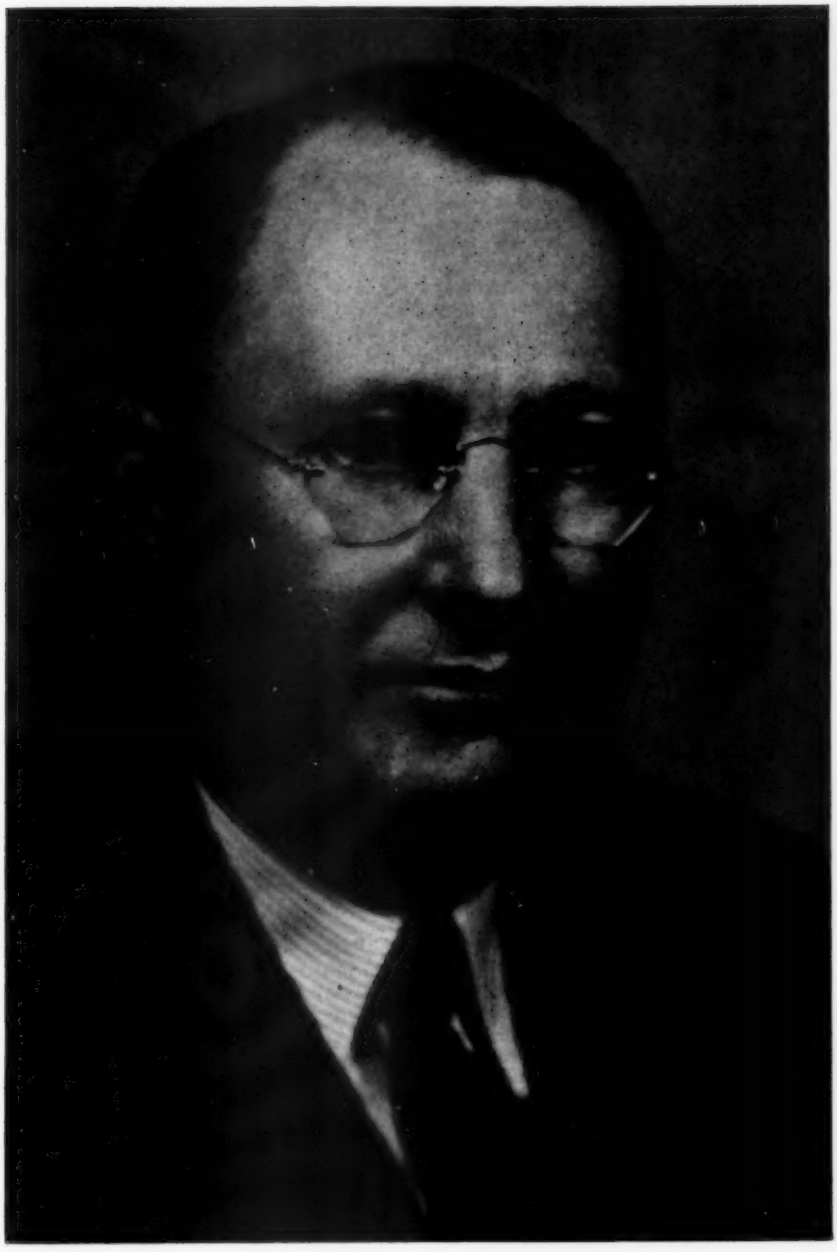
Current Publications

THE JOURNAL has not attempted, in the past, to publish reviews or even notices of bulletins and other forms of current entomological literature and it is not necessary or desirable that it should inaugurate such a policy at the present time. The Bureau of Entomology and Plant Quarantine, of the U. S. Department of Agriculture, and other agencies, issue such notices and are in much better position to do so than is the Journal.

However, members have, from time to time, called attention to noteworthy bulletins with the suggestion that some mention of them be made in the Journal so that entomologists who might not have their attention called to the publications otherwise, particularly men stationed in the field, might be advised of their appearance and secure them at an earlier date than they might otherwise be able to do.

The suggestion seems to be a good one and members are invited to call attention to publications which seem to fall in this category, submitting, where convenient, statements concerning them in form suitable for publication. Such notes should usually be brief and should not attempt to follow the form of the regular book notices or reviews. The editor will attempt to publish such notes at the earliest possible date, possibly inserting them at the page-proof stage of publication. They will be used as fillers in any convenient position in the Journal.

The two notes appearing in this issue of the Journal may serve to indicate, in a very general way, the form and scope of notices desired.



OBITUARY

Lee Abram Strong

On June 2, 1941, Dr. Lee A. Strong passed away after a lingering illness in Madera Canyon near Tucson, Arizona, marking the peak of the third epoch in American economic entomology. Preceding this epoch were two periods. One, the pioneering in the study of insects. This we know as the taxonomic period and is associated with such names as Say, Leconte, Osten-Saken, and Horn. Then comes the second epoch with Harris, Fitch, and the first Chief of the federal work on insects, C. V. Riley. Riley and his associates laid the groundwork for economic entomology. This epoch was carried to its peak by

L. O. Howard, really its founder and greatest champion. Howard brought American economic entomology to the attention of the world. Following this period was the third period, that of plant quarantines inaugurated in the Federal Department by C. L. Marlatt, and it was in this period that Strong first appears on our horizon. With him very largely we must identify this period. He is to this period what Howard was to the last.

He was born in Russell, Iowa, the son of farmers, Hez G. and Julia B. (Ashby) Strong, who soon thereafter moved to Nebraska where Lee received his only formal education in the public schools of Nehawka. Very early in his manhood he went to California and it was here that his career began in the field which finally he epitomizes. He started as a horticultural inspector for the Los Angeles County Horticultural Commission in August 1910. Four years later he was appointed plant quarantine inspector at Los Angeles Harbor. "In those days," he once stated, "I had no office, and had to learn of ships' arrivals from cigar stores. I finally made a deal for desk room in the office of the old San Francisco and Portland Steamship Company office, in return for checking baggage. I also swept out. In 1914, I found a vacant office in the old wharfinger's building at Berth 88, and moved in. I couldn't find anyone to kick me out, so I held on till the State finally got its own offices."

In 1912, he was appointed quarantine inspector by the State Commissioner of Horticulture, with headquarters in San Francisco. In April 1914, he was placed in charge of inspection at San Pedro, the port of entry for Los Angeles and the second in importance in California. In June 1917, he was appointed Deputy Quarantine Officer of the State Commission of Horticulture, with headquarters at Los Angeles, and given charge of all quarantine work in southern California.

From November 16, 1912, to March 19, 1918, he served as Collaborator of the Federal Horticultural Board. In March 1918, he resigned as Deputy Quarantine Officer to join the Army and served as Sergeant with the 537th Engineers from March 20, 1918, to July 15, 1919, twelve months of which time was in France with the American Expeditionary Force.

On his return to civil life from army service in July 1919, he was appointed Deputy Quarantine Officer with headquarters in San Francisco, this appointment involving the general field supervision of the quarantine work throughout the State. On November 1, 1920, he was made Chief Deputy Quarantine Officer of the California State Department of Agriculture. In June 1921, he was made Chief of the Bureau of Plant Quarantine of the State Department of Agriculture, with headquarters at Sacramento—a new position. In this position he was charged with the responsibility of enforcing all quarantines at all points in California; of the direction of all port inspection offices at the maritime ports of California, as well as the activities of the 50 horticultural commissioners and some 250 horticultural inspectors stationed at interior points throughout the State, in so far as their work applied to the enforcement of plant quarantines. In 1923, the Bureau of Pest Control of the California Department of Agriculture was consolidated with the Bureau of Plant Quarantine, and Dr. Strong was made the chief of the Bureau.

He was one of the organizers of the Western Plant Board, and served as Secretary of that organization for several years. The great usefulness of this Board to the states concerned led to the organization of similar regional Boards covering the balance of the 48 states. These Boards are the Central Plant Board, the Southern Plant Board, and the Eastern Plant Board. The coordination of the work of these Boards was provided by the organization of a National Plant Board, of which he was first chairman.

From December 1, 1923, until June 1925, he was in charge of port inspection for the Federal Horticultural Board of the U. S. Department of Agriculture in Washington, D. C. In his position as Chief, Plant Quarantine Inspection Service, of this Board, Dr. Strong was responsible for all foreign quarantines and regulations issued under the Plant Quarantine Act in the District of Columbia and all ports of entry in the field. He initiated and executed independently inspection policies, advised and assisted in the drafting of regulations and their interpretation, and through consultation with State and Federal officers brought about close cooperation in the enforcement of various quarantines and regulatory orders of the Board. He resigned on June 30, 1925, to accept the position of Assistant Director of the California State Department of Agriculture, during which time he served as a Collaborator of the Federal Horticultural Board. He served as Assistant Director of the California State Department of Agriculture until December 2, 1929, when he was appointed Chief of the Plant Quarantine and Control Administration, later known as the Bureau of Plant Quarantine, of the U. S. Department of Agriculture. In 1933, upon the retirement of Dr. C. L. Marlatt, he became Chief of the Bureau of Entomology, and on July 1, 1934, when the Bureau of Entomology and the Bureau of Plant Quarantine were consolidated he was made Chief of the newly created Bureau, a position which he held until his death.

In the Spring of 1938, Dr. Strong served as Chairman of a Commission of Technical Experts, appointed by the Secretary of Agriculture to confer at The Hague with a similar Commission of the Netherlands Government under the provisions of Article X of the Trade Agreement between the United States and the Netherlands. While on this trip conferences pertaining to entomological and plant quarantine problems were held in England, France, Belgium, and Switzerland. In 1935, 1937, and 1938, conferences were held in Mexico with the agricultural officials of that country which resulted in better understanding and closer cooperation is pest control problems common to both countries.

He was a member of the American Association of Economic Entomologists, being president in 1935; of the Entomological Society of Washington; and of the Cosmos Club. In 1938, he received the honorary degree of Doctor of Science from Louisiana State University.

Dr. Strong was a self-educated man in the sense that he had no college training, but throughout his work he showed soundness of judgment and an appreciation of basic science in applied entomology and pathology. His clearness of expression and leadership led to his recognition as a national authority in matters pertaining to economic entomology and plant quarantines.

On March 2, 1921, he was married to Miss Edith M. Colton. He is survived by Mrs. Strong and three children, Madeleine Virginia, Lee A., Jr., and Helen Tesora; three sisters, Mrs. Tesora Fleury, Mrs. Savena Collard, and Mrs. Marjorie Knopp; and four brothers, Messrs. George, Morris, Courtland, and Nestley Strong. He was buried with military honors in Arlington National Cemetery overlooking the Capitol of the nation.—6-11-41.

REVIEWS

Insect Pests of Farm, Garden and Orchard, by Leonard Marion Peairs, Ph.D., Professor of Entomology, West Virginia University, 4th ed., 8vo., cloth, 549 pp., 648 illus., N. Y., John Wiley & Sons, 1941, $4.00.

In 1902 there was published a small volume bearing the title "Insects Injurious to Staple Crops," under the authorship of Professor E. Dwight Sanderson. That work brought together in compact form much information concerning the life history and control of injurious insects which previously had been widely scattered through such original sources as the publications of the United States Department of Agriculture, the various State Experiment Stations, and books on economic entomology. The book proved to be of much practical usefulness and attained wide popularity. When the edition was exhausted, instead of reissuing it, there was prepared and published in 1912 a work, entirely distinct, though somewhat similar in scope, under the same authorship, entitled "Insect Pests of Farm, Garden and Orchard." This too became a successful and widely used work, and steady demand made it necessary to issue second and third editions in 1921 and 1931 respectively. Both of these were revised and enlarged and in part rewritten by Dr. Peairs as junior author. Now in 1941 the continued demand is met by the newly issued fourth edition, here under consideration. Dr. Sanderson, author of the preliminary book, of the first edition, and co-author of the second and third editions, has withdrawn from participation in the work, and, in accordance with his wish, his name has been omitted from the title page of the present book. Mention is here made of these facts, not only because of bibliographical interest, but also as an illustration of necessity for frequent thorough and drastic revision in works of this character, and furthermore is an index of the great progress made during the past few decades in economic entomology. It is regretted that the scope of this notice and limitations of space forbid detailed discussion of the subject matter of the book's various subdivisions. The treatment while concise appears to be quite adequate for ordinary use, and excellent judgment has been manifested in selection of material to be included as well as in that which had to be omitted, and particular emphasis has been placed upon the resumes of very latest available information, especially in such phases as the shifting of economic conditions, the distribution of introduced pests, changes in farm practice, and most recent developments in new chemicals and new machinery used in insect control. Indeed a page by page comparison of a considerable portion of the fourth with the third editions, reveals that the entire book has had to be rewritten in order that its contents might conform to latest discoveries and developments. There are chapters treating of the life history, habits and control of the principal insects injurious to field crops, grasses, cereal grains, cotton, leguminoous, solanaceous and garden crops. Likewise of insects injurious to small fruits, grapes, orchard and citrus fruits, stored products and household goods, as well as those injurious to man and to domestic animals. Particularly helpful in connection with these discussions are the carefully selected references therewith to further information on a given pest or subject. The illustration too are numerous and well selected and add much to the usefulness of the book for ready reference, particularly when consulted by farmers and other nontechnical readers to whom pictures would be of aid in ready identification of a particular insect.

On the whole, it would appear that this latest fourth edition not only is fully worthy of its predecessors, but, in view of the tremendous growth during past decades of economic entomology, it probably will attain even wider usefulness.

J. S. WADE

LEAD ARSENATE AND THE CONSUMER

The U. S. Public Health Service has just issued Bulletin No. 267, entitled "A study of the effect of lead arsenate exposure on orchardists and consumers of sprayed fruit."

This bulletin reports in detail studies continued through a period of three years in the Wenatchee, Washington, region. The authors include Dr. Paul A. Neal and a staff which includes surgeons, statisticians, biochemists and toxicologist. To the layman it seems that all possible measurable effects of lead arsenate upon the handler and consumer have been thoroughly investigated. The report comprises some 181 pages.

The purpose of the bulletin is obviously to arrive at a fair and impartial basis for the determination of restrictions which should be placed on the use of the lead arsenate in orchards and on the residues which may be permitted to remain on fruits in commerce.

Entomologists concerned with the problem will wish to make a detailed study of the findings. A brief summary of some of the conclusions may, however, be in place here. On page x, in the general summary, the following statement is found: ". . . Chemical analyses of unwashed apples of the kind eaten by residents of the district showed that the spray residue load averaged about 20 times the amount found on apples shipped in interstate commerce." On the following page, " . . . there are unusual opportunities for children to be exposed to lead arsenate insecticide sprays and spray residues on branches, leaves and grass in addition to the lead arsenate spray residues they ingest on apples. . . . There was no indication of adverse effects of lead arsenate on the health of these children." And on page 69, the following cautious statement: "No relation could be found, however, between ingestion of washed and unwashed apples and the occurrence of any of the symptoms, signs or laboratory findings known to be a part of the symptomatology of lead or arsenic intoxication. It appears that the increases in lead and arsenic assimilation that result from eating lead arsenate spray residues on apples and pears do not overtax the ability of the body to excrete lead and arsenic."

The bulletin may, presumably, be secured from the Public Health Service; it is listed for sale by the Superintendent of Documents, Washington, D. C., for 40 cents.

NOTES

Program of the Pacific Slope Branch Meeting
June 18, 19, 20, 1941

Joint sessions with the Entomological Club of Southern California, California Entomological Club, and Pacific Coast Entomological Society

Vegetable insect problems of the Pacific Southwest. Roy E. Campbell, *U. S. Dept. of Agriculture, Alhambra, California.*

Isolation cage studies to determine the effect of certain Hemipterous and Homopterous insects on sugar beets grown for seed in the Southwest. O. A. Hills, *U. S. Dept. of Agriculture, Phoenix, Ariz.*

Control experiments on the tomato fruitworm in southern Colorado. John L. Hoerner, *Colorado Agr. Expt. Sta., Fort Collins, Colo.*

Preliminary studies on the control of pillbugs and sowbugs. R. M. Bohart and A. M. Mallis, *Univ. of California, Los Angeles.*

Preliminary experiments on the silverfish, *Ctenolepisma urbani* Slabaugh. Arnold Mallis, *Univ. of California, Los Angeles.*

Some preliminary tests of the effects of infra-red irradiation on the American cockroach. G. F. MacLeod, *Univ. of California, Berkeley.*

A preliminary report on the control of the western twelve-spotted cucumber beetle, *Diabrotica 11-punctata* (Mannerheim) in fruit orchards. A. E. Michelbacher, G. F. MacLeod, and R. F. Smith, *Univ. of California, Berkeley.*

Comparative biology of two chalcidoid parasites of the black scale, *Saissetia oleae* (Bern.). S. E. Flanders, *Citrus Experiment Station, Riverside, Calif.*

Host population density and reproduction of entomophagous parasites. Paul H. De Bach and Harry S. Smith, *Citrus Experiment Station, Riverside, Calif.*

A method of simulating airplane application of insecticides to tall plants in experimental plots. O. A. Hills and Van E. Romney, *U. S. Dept. of Agriculture, Phoenix, Arizona.*

A morphological difference between California red scale and yellow scale. Harold R. Yust, *U. S. Dept. of Agriculture, Whittier, Calif.*

Formation of the scale covering by the California red scale. R. C. Dickson, *Citrus Experiment Station, Riverside, Calif.*

Commodity treatment for the alleviation of plant quarantines. D. B. Mackie, *California State Dept. of Agriculture, Sacramento.*

A comparison of the reaction of resistant and non-resistant strains of California red scale to fumigation with HCN. Harold R. Yust, R. L. Busbey, and Howard D. Nelson, *U. S. Dept. of Agriculture, Whittier, Calif.*

Double versus single fumigation for the control of California red scale. David L. Lindgren, *Citrus Experiment Station, Riverside, Calif.*

Distribution of hydrocyanic acid gas. Robert A. Fulton, R. L. Busbey, and Harold R. Yust, *U. S. Dept. of Agriculture, Whittier, Calif.*

The absorption and retention of HCN by citrus tissues. E. T. Bartholomew, Walton B. Sinclair, and D. L. Lindgren, *Citrus Experiment Station, Riverside, California.*

The control of black scale in olive orchards by calcium cyanide dusting. A. F. Kirkpatrick, *American Cyanamid & Chem. Corp., Azusa, Calif.*

The effect of methyl bromide fumigation on strawberry planting stocks for the control of *Paria canella quadrinotata.* George Kido, *Univ. of California, Berkeley.*

Population and mortality studies of Lecaniine scale insects. Ralph H. Smith, *Univ. of California, Los Angeles.*

Symposium: *Relationships between systematic and economic entomology.*

Systematic entomology and its bearing on the problems of economic entomology, E. O. Essig, *Univ. of California, Berkeley.*

Present status of entomological nomenclature. E. G. Linsley, *Univ. of California, Berkeley.*

The needs of American systematic entomology, G. F. Ferris, *Stanford University.*

Symposium: *Petroleum Oil Sprays on Deciduous and Citrus Fruit Trees.*

Some recent advances in the chemistry and physics of spray oils and emulsions. W. M. Hoskins, *Univ. of California, Berkeley.*

Methods of determining oil deposit. A. W. Cressman, *U. S. Dept. of Agriculture, Whittier.*

Physiological and physical effects of spray oils on deciduous trees. P. A. Young, *Texas Agricultural Expt. Sta., Jacksonville.*

Effects of petroleum oil sprays on citrus.

a. Physiological and physical effects on citrus trees. P. W. Rohrbaugh, *California Fruit Growers Exchange, Ontario.*

b. Effects on the quality of citrus fruits. W. B. Sinclair, E. T. Bartholomew, and Walter Ebeling, *Citrus Experiment Station, Riverside.*

Toxicants used with oil for the control of deciduous fruit insects. L. M. Smith, *Univ. of California Deciduous Fruit Field Station, San Jose.*

Toxicants used with oil for the control of citrus fruit insects. Walter Ebeling, *Citrus Experiment Station, Riverside.*

Toxicants in relation to the physical properties of petroleum oil. E. R. de Ong, *San Francisco.*

Present status of rotenone and rotenoids. R. C. Roark, *U. S. Dept. of Agriculture, Washington, D. C.*

The effectiveness of combinations of cube resins and petroleum oil against California red scale, A. W. Cressman and B. M. Broadbent, *U. S. Dept. of Agriculture, Whittier, Calif.*

Solubilizers for extracts of rotenone-bearing roots and petroleum oil. J. F. Kagy, and A. M. Boyce, *Citrus Experiment Station, Riverside, Calif.*

Some problems in western forest entomology, K. A. Salman, U. S. Dept. of Agriculture, Berkeley.

Observations on *Matsucoccus bisetosus* Morrison, a potential scale enemy of California pines. Howard L. McKenzie, *U. S. Dept. of Agriculture, Berkeley.*

Preliminary studies on the control of the Lodge pole needle miner, *Recurvaria milleri* Busck. J. S. Yuill, *U. S. Dept. of Agriculture, Berkeley.*

A recent development in the control of forest insects in pine stands in Northeastern California. J. W. Bongberg, *U. S. Dept. of Agriculture, Berkeley*

Biology of a weevil, *Cylindrocopturus eatoni* Buchanan, injurious to western yellow pine reproduction, C. B. Eaton, *U. S. Dept. of Agriculture, Berkeley.*

The Pandora moth, *Coloradia pandora* Blake, a defoliator of lodgepole pine in Colorado. N. D. Wygant, *U. S. Dept. of Agriculture, Berkeley.*

The effect of climate on timber losses caused by

insects in ponderosa pine in California. R. C. HALL, *U. S. Dept. of Agriculture, Berkeley.*

Controlling the mountain pine beetle in lodgepole pine by penetrating sprays. JAMES C. EVENDEN, *U. S. Dept. of Agriculture, Coeur d'Alene, Idaho.*

Life history and control of the ash plant bug in California, R. L. USINGER, *Univ. of California, Davis.*

Some characteristics of *Apis indica*, the oriental honeybee, in China. CLAUDE R. KELLOGG, *Fukien University, Foochow, China.*

Observations on the purported resistance of the honeybee to American foulbrood. J. E. ECKERT, *Univ. of California, Davis.*

Pollen grains in nectar and in honey. FRANK E. TODD and GEO. H. VANSELL, *U. S. Dept. of Agriculture, Davis.*

The citrus bud mite, *Eriophyes sheldoni* Ewing. A. M. BOYCE and R. KORSMEIER, *Citrus Experiment Station, Riverside, Calif.*

Radioactive elements in entomological research. R. CRAIG, *Univ. of California, Berkeley.*

The osmotic pressure of the blood of several common species of insects. E. N. FELS, *Univ. of California, Berkeley.*

Studies on the permeability of the integument of fly larvae. MARC RICKS, *Univ. of California, Berkeley.*

Reactions of the citrus thrips to sugar: The role of sugar in poisoned bait. FRANCIS MUNGER, *U. S. Dept. of Agriculture, Whittier.*

The effect of pH on the toxicity of solutions of tartar emetic and other organic antimony compounds to the greenhouse thrips, C. O. PERSING, B. R. BARTLETT and R. L. BEIER, *Citrus Experiment Station, Riverside.*

Laboratory toxicological studies on the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché). BLAIR, R. BARTLETT and C. O. PERSING, *Citrus Experiment Station, Riverside.*

Preliminary investigations of the electrical properties of insecticidal dusts. JAMES W. HANSON, *Univ. of California, Berkeley.*

Cotton dusting experiments in the San Joaquin Valley with special reference to the control of *Lygus hesperus* Knight. GORDON L. SMITH, *Univ. of California, Shafter.*

Recent advances in sylvatic plague surveying, M. A. STEWART, *Univ. of California, Davis.*

Tests of organic compounds as repellents for blowflies attacking sheep. E. S. LOEFFLER, *Univ. of California, Berkeley.*

Cattle louse control. (Motion picture in color.) *Texas Gulf Sulfur Co.* Discussion by M. A. STEWART, *Univ. of California, Davis.*

ROY E. CAMPBELL
Secretary-Treasurer
Pacific Slope Branch

GEORGIA ENTOMOLOGICAL SOCIETY

Fifth Annual Spring Meeting, Wesleyan College, Macon, Georgia, April 5, 1941

The meeting was called to order by President C. H. Alden at 2.30 P.M. Dr. P. M. Gilmer and Mr. O. I. Snapp were designated to serve as a nominating committee and Mr. T. L. Bissell and Mr. P. W. Fattig as a resolutions committee.

Mr. Alden called upon Dr. T. H. McHatton of the University of Georgia to introduce Mr. Robert C. Berckmans of Macon, Ga. Mr. Berckmans delivered a short address of welcome, in which he recounted some of his earliest associations with Dr. C. V. Riley and emphasized the importance of entomology to public welfare.

Mr. Alden responded for the society and proceeded with his very stimulating presidential address on the "The Good Insects," in which he summarized the debt of mankind to the insects.

In the business meeting which followed, the report of the Secretary-Treasurer was read and accepted. Greetings to the Society from Mr. Perry Glick, now of Waco, Texas, and Dr. B. J. Kaston, of Gainesville, Ga., were read.

Dr. P. M. Gilmer, chairman of the membership committee, moved that membership be extended to the following persons: Mr. Rober C. Berckmans, Macon; Dr. Justin Andrews, Atlanta; Mr. W. H. Clarke, Cornelia; Mr. G. L. Carver, Macon. Motion carried.

Dr. H. O. Lund, chairman of the State insect survey committee, reported considerable progress in the accumulation of collection records and Dr. Gilmer urged maximum cooperation with the Survey Committee.

The following program was then presented:

Parasite work of the State Department of Entomology (moving pictures in color)—a pictorial review of the work of the parasite laboratory at *Cornelia, Ga.*.....MR C. H. ALDEN

Life history of *Pseudoclista globosa*, parasite of the cowpea curculio—a fundamental study illustrated with photomicrographs.....MR. T. L. BISSELL

Leaf-cutter ants in Western Louisiana (moving pictures in color)—illustrating the ravages, biology, and control of the species.....MILLEDGE MURPHEY

Color in the world of insects (slides in color) illustrating some 130 species of colorful Georgia insects.....H. O. LUND

Trying to correct a Holland error—a study of cocoon attachment of *Telea polyphemus*.....MRS. L. FIELDING LANIER

Malaria Control in Georgia—a review of the development and progress of malaria control in the State..JUSTIN ANDREWS

The secretary was instructed by motion to cast a unanimous ballot for the following officers:

President, MILLEDGE MURPHEY, *Atlanta.*
Vice president, P. W. FATTIG, *Atlanta.*
Secretary-Treasurer, H. O. LUND, *Athens.*
Historian, T. L. BISSELL, *Experiment.*

Exhibits of butterfly trays and polyphemus cocoons were shown by Mrs. Lanier, and Dr. Lund exhibited some large and colorful insects from the Malay Penninsula and from the Philippine Islands and some living grubs and adults of *Dynastes tityrus.*
—5-11-41.

HORACE O. LUND
Secretary-Treasurer

COTTON STATES BRANCH MEETINGS FOR 1942

The Cotton States Branch of the American Association of Economic Entomologists will hold its annual meetings in 1942 in conjunction with the Association of Southern Agricultural Workers. These meetings will be held in Memphis, Tennessee on February 4, 5, and 6, 1942. The Executive Headl quarters for the Association of Southern Agricultura-Workers will be in the Peabody Hotel, but Cotton States Branch headquarters will be announced at a later date.

FIFTH ANNUAL TOBACCO INSECT CONFERENCE

The fifth annual conference of entomologists working on the control of tobacco insects will be held at Oxford, N. C., July 22, 23, and 24, 1941.

The Tobacco Test Farm of the North Carolina Department of Agriculture is located at Oxford, and an interesting program is being planned.

The sessions will be informal and devoted principally to round table discussion of research and extension work on tobacco insects.

On July 24, a field trip will be made to observe cultural and harvesting methods for flue cured tobacco in North Carolina.

The program committee consists of Z. P. Metcalf, C. F. Stahl, S. Marcovitch, and W. D. Reed.

CLASSIFIED

Advertisements of commodities for sale or exchange or of services will be entered at 50 cents per issue or $2 per year. Advertisements requesting information for use in publications will be charged at the rate of $1 per advertisement to run as long as space permits. All notices and cash should be sent in advance to Ernest N. Cory, College Park, Md., by the 15th of the month preceding publication.

PHOTOGRAPHS OF ENTOMOLOGISTS. The undersigned desires photos of entomologists to add to the collection now deposited in the Department at Ohio State University. This collection now numbers over 400 portraits, many of them having been included in the "Fragments of Entomological History." It is hoped that a supplement to that volume may include many more and any contributions will be gratefully welcomed. Herbert Osborn, Ohio State University, Columbus, Ohio.

PART THREE of "A Manual of Entomological Equipment and Methods" will be published as soon as sufficient information is compiled and contributed to produce a satisfactory volume. If you have any contributions of subject matter similar to that found in Parts 1 and 2, which you would like to have appear in concise form in this new volume, please send the figures and written matter to Alvah Peterson, Ohio State University, Columbus, Ohio, at your earliest convenience.

All contributions will appear under the contributor's name as in Part 2. Any information or suggestions for improving the Manual will be appreciated.

FOR SALE: "The North American Bees of the Genus Osmia" by Grace A. Sandhouse, issued as Memoir No. 1 of the Entomological Society of Washington; also single numbers or complete sets of the Proceedings, Ent. Soc. Wash., 1884-1940. For details see Journal of Economic Entomology, Vol. 33, No. 6, p. iii, Dec., 1940. F. W. Poos, Corresponding Secretary. Address: Bureau of Entomology and Plant Quarantine, Washington, D.C.

A SPECIAL SALE PRICE of $3.25 per part either part I or part II of "A Manual of Entomological Equipment and Methods" by Alvah Peterson is announced for a limited period of time *provided* the purchaser sends *cash* (U.S. value) with the order and places the order directly with the author and *not* through a book dealer. Postage is prepaid in the United States; outside the United States add 50 cents per book. The standard sale price for part I is $3.75 and for part II $4.50. To obtain the special price send orders with cash directly to Alvah Peterson, Ohio State University, Columbus, Ohio.

FOR SALE: Journal of Economic Entomology, Vols. 25, 1932, to Vol. 33, 1940, inclusive, 9 complete volumes—$25.00. Also: Soap and Sanitary Chemicals Magazine, Vols. 8, 1932, to Vol. 16, 1940, inclusive, complete 9 volumes except May, 1939—$15.00. The Review of Applied Entomology, Series A., Vols. 20, 21, and 22, complete with indices—$10.00. Journal American Chemical Society, Industrial and Engineering Chemistry, and Chemical Abstracts, all for year 1931—$5.00. All prices f.o.b., Walla Walla, Wash. Russell S. Lehman, Box 415, College Place, Wash.

FOR SALE: The Blatchley Insect and Nature Books. Rhynchophora or Weevils of Northeastern America (with C. W. Leng), $4.00; Supplement IV, 1928 (a few copies only), $0.50; Orthoptera of Northeastern America, cloth $6.00, paper, $5.00; Heteroptera or True Bugs of Eastern North America, cloth $10.00, paper, $9.00. Terms, cash with order.

Also, Indiana Weed Books; Fishes of Indiana; Blatchleyana I and II; Gleanings from Nature; Woodland Idyls; A Nature Wooing at Ormond by the Sea; My Nature Book; In Days Agone; South America as I Saw It. Prices on application. Address W. S. Blatchley Club, Earl Brooks, Librarian, Noblesville, Indiana.

Index to Advertisers

American Association of Economic Entomologists x
Carbide and Carbon Chemicals Corporation, New York vi
Journal of Economic Entomology xi
McCormick Sales Co., The, Baltimore, Md. iv
McLaughlin Gormley King Co. x
Penick and Company, S. B., New York City vii
Pennsylvania Salt Manufacturing Co. viii
Pratt Co., The B. G., New York City ix
Standard Agricultural Chemicals, Inc., Hoboken, N.J. iv
Stauffer Chemical Co., New York, N.Y. vii
United States Rubber Co., New York, N.Y. v

JOURNAL OF ECONOMIC ENTOMOLOGY
Official Organ American Association of Economic Entomologists

Vol. 34 August 1941 No. 4

History of the Cotton States Branch of the American Association of Economic Entomologists[1]

OLIVER I. SNAPP, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine, Fort Valley, Georgia*

Although the Cotton States Branch is now only 15 years old, it grew from an organization that is nearly as old as the American Association of Economic Entomologists. The parent Association was organized in 1889, whereas the organization that later became its Cotton States Branch held its first meeting on August 2, 1904, at Jackson, Miss. This meeting was called to consider especially the boll weevil, which had reached Louisiana by that time and was rapidly moving northward and eastward to other cotton-growing States. It was attended by C. E. Chambliss of South Carolina, H. A. Morgan of Louisiana, Wilmon Newell of Georgia, E. D. Sanderson of Texas, W. V. Reed of Mississippi, and W. D. Hunter and A. W. Morrill of the Bureau of Entomology, United States Department of Agriculture, Dallas, Texas, Organization was effected with C. E. Chambliss as chairman and A. W. Morrill as secretary. Uniform State quarantine laws and regulations to prevent the introduction of the boll weevil into uninfested areas was the chief subject discussed at this meeting, and resolutions to that effect were unanimously adopted. It was voted that, in order to facilitate the future transaction of business in connection with State boll weevil quarantines, a permanent organization be established among the official entomologists of the cotton States, and thus the Association of Official Entomologists of the Cotton Belt was formed.

The second meeting of the Association was held at Atlanta, Ga., on May 6, 1905, in the office of the State entomologist at the Capitol. Messrs. Chambliss, Morgan, then director of the Tennessee Agricultural Experiment Station and head of the department of zoology of the University of Tennessee, Newell, then State entomologist of Louisiana, Hunter, and Morrill were present, as well as Gordon M. Bentley, instructor in North Carolina State College and assistant State entomologist of North Carolina; Wm. Harper Dean, assistant State entomologist of Georgia; Glenn W. Herrick, State entomologist of Mississippi; A. C. Lewis, assistant State entomologist of Georgia; R. S. Mackintosh, Alabama State horticulturist and quarantine agent; J. L. Phillips, State entomologist of Virginia; and Ralph I. Smith, State entomologist of Georgia. The group was photographed on the steps of the State Capitol at Atlanta on May 6, 1905, and this picture is reproduced in figure 1. Discussions at this meeting centered on various phases of the boll weevil work and quarantines to prevent the spread of this insect. Plans were discussed for a meeting of the Association at New Orleans, La., at the time of the next meeting of the American Association for the Advancement of Science.

Nine meetings of a cotton boll weevil institute, sponsored by the Association of Official Entomologists of the Cotton Belt, were held at Dallas, Texas, during the period April 6, 1907, to June 25, 1908. W. D. Hunter served as chairman and W. Dwight Pierce as secretary of these meetings. The meeting on April 6, 1907, was attended by F. C. Bishopp, R. A. Cushman, W. E. Hinds, W. A. Hooker, W. D. Hunter, W. D. Pierce, F. C. Pratt, and W. W. Yothers. Dr. Pierce discussed the economic aspects of the study of weevil parasites. On April 27 Messrs. Bishopp, Hunter Pratt, Pierce, Yothers, E. A. Schwarz, and Springer Goes were present. Mr. Yothers discussed boll weevil hibernation and Mr. Schwarz told about the early history of entomology in Texas.

[1] Address of the Chairman, Cotton States Branch. Presented at the Birmingham, Alabama, meeting, February 8, 1940. Published at the request of the Cotton States Branch.

FIG. 1.—Association of Official Entomologists of the Cotton Belt, Atlanta, Ga., May 6, 1905. (1. Wilmon Newell. 2. A. C. Lewis. 3. A. W. Morrill. 4. Gordon M. Bentley. 5. H. A. Morgan. 6. C. E. Chambliss. 7. Wm. Harper Dean. 8. W. D. Hunter. 9. Glenn W. Herrick. 10. R. S. Mackintosh. 11. J. L. Phillips. 12. Ralph I. Smith.)

On July 2 Messrs. Hinds, Hooker, Hunter, Pratt, Pierce, and Yothers were preset, as well as E. A. Sanborn, C. S. Spooner, M. Alfredo Broggi, agricultural engineer of Peru, and C. P. Lounsbury, entomologist of Cape Colony, South Africa. Prof. Lounsbury spoke of entomology in South Africa. On August 3 Messrs. Bishopp, Cushman, Hinds, Hooker, Hunter, Pierce, Spooner, and Yothers were present. Mr. Yothers spoke of the effects of ground temperature on the weevil, Dr. Hunter on this trip to Mexico, and Dr. Hooker on ticks.

On August 31, there were present Messrs. Bishopp, Cushman, Goes, Hinds, Hooker, Hunter, Pratt, Pierce, Spooner, Yothers, and A. W. Morrill of Florida. Dr. Morrill told of the citrus whitefly problem in Florida. On September 2 there were present Messrs. Bishopp, Goes, Hinds, Hooker, Hunter, Pratt, Pierce, Spooner, Yothers, and Newell. Prof. Newell spoke about the Argentine ant and the tick work. On October 16 Messrs. Bishopp, Cushman, Goes, Hooker, Pratt, Pierce, W. D. Hunter, and J. S. Hunter of California were present. J. S. Hunter told of an expedition to the Galapagos Islands in 1905. On October 21, 1907, those present were Messrs. Bishopp, Cushman, Goes, Hinds, Hooker, Hunter, Pratt, Pierce, Clarence E. Hood, W. W. Froggatt from New South Wales, and L. O. Howard from Washington, D. C. Prof. Froggatt told of Australian entomology and Dr. Howard told of the progress of parasite introduction, with especial regard to the gypsy moth parasites. On June 25, 1908, there were present Messrs. Cushman, Goes, Hood, Hunter, Pratt, Pierce, Charles E. Jones, E. S. Tucker, and Herbert Wood, and David Griffiths of Washington. Dr. Griffiths told of the work with cactus.

ASSOCIATION OF COTTON STATES ENTOMOLOGISTS.—Regular meetings were not held by the Association of Official Entomologists of the Cotton Belt, but informal meetings were called when the Southern

States were confronted with an entomological problem that demanded the attention of their entomologists. Sometime during the period 1906–11 the name of the organization was changed to Association of Cotton States Entomologists. It was agreed that the Association should be informal, without regular constitution, by-laws, or dues, and that meetings should be called whenever entomological problems occurring in the South seemed to demand them. The fact that many of the problems relating to cotton pests did not occur outside the Cotton Belt and were therefore rarely dealt with in the national entomological meetings led to the adoption of the name Cotton States Entomologists for the group. National entomological meetings were held mostly in the Northern States at that time, and as southern entomologists found it difficult to attend these meetings regularly, it was felt that a southern association of entomologists would be of great help in promoting the solution of Cotton Belt insect problems, and that the more frequent meetings of entomologists in the South would promote a deeper interest in the work of the American Association of Economic Entomologists.

Important meetings of the Association of Cotton States Entomologists were held in Atlanta, Ga., on December 5 and 6, 1911, and in Washington, D. C., on December 29 for the purpose of considering the various boll weevil quarantine regulations then in force in the various States with a view of obtaining uniformity. The proceedings of these meetings were published in the February 1912 issue of the JOURNAL OF ECONOMIC ENTOMOLOGY (v. 5, no. 1). Officers at that time were W. E. Hinds, president, and A. F. Conradi, secretary.

Citrus canker and other matters that required the attention of southern entomologists led to a meeting of the Association at the University of Florida, Gainesville, on March 29, 30, and 31, 1917. Another meeting of the Association in 1917 was held at the Monteleone Hotel in New Orleans, La., on October 4, with W. E. Hinds presiding. Those present were Ed. L. Ayers, Houston, Texas; E. R. Barber, New Orleans; S. W. Bilsing, College Station, Texas; B. R. Coad, Tallulah, La.; W. R. Dodson, Baton Rouge, La.; W. E. Hinds, Auburn, Ala.; T. E. Holloway, New Orleans; W. D. Hunter, Washington, D. C.; Wilmon Newell, Gainesville, Fla.; H. L. Sanford, Washington, D. C.; E. E. Scholl, Austin, Texas; Franklin Sherman, Raleigh, N. C.; and E. Lee Worsham, Atlanta, Ga. The minutes of this meeting were recorded by T. E. Holloway in the absence of Secretary A. F. Conradi. Dr. Hunter spoke of the pink bollworm and considerable discussion of quarantines followed. The spiny whitefly and sweetpotato weevil, scouting for these insects, and quarantine measures against them were other subjects discussed at this meeting.

AFFILIATION WITH ASSOCIATION OF SOUTHERN AGRICULTURAL WORKERS.—An important meeting of the Association of Cotton States Entomologists at which the attendance and program exceeded that of any previous meeting was held at Vicksburg, Miss., and Tallulah, La., on March 1, 2, and 3, 1920. More than 50 persons attended this meeting (Fig. 2), and the finding of the pink bollworm in Louisiana added special interest to it. W. E. Hinds presided and A. F. Conradi, secretary, prepared full proceedings of the meeting. These officers were reelected at Vicksburg. The following resolution was adopted on March 3, 1920, at Vicksburg: "Be it resolved that the thanks of this Association be extended to the Association of Southern Agricultural Workers for its invitation to affiliate with that Association, that such invitation be hereby accepted, and that the President of our Association be delegated and authorized to arrange for such affiliation." Thus from 1921 to 1936 the group met annually as the Entomology Section of the Association of Southern Agricultural Workers.

Interest in the Association of Cotton States Entomologists increased following the large meeting in 1920. It met in Memphis, Tenn., in 1923, Birmingham, Ala., in 1924, and Atlanta, Ga., in 1925. More than 100 persons attended the meeting in Birmingham. At the annual meeting in Birmingham on January 10 and 11, 1924, it was voted to apply for recognition as a branch of the American Association of Economic Entomologists. As this matter was not presented in time for action by that Association at its annual meeting in Washington, D. C., in 1924, the Association of Cotton States Entomologists again considered the matter at

FIG. 2.—The Association of Cotton States Entomologists in session at Vicksburg, Miss., and Tallulah, La., March 1–3, 1920.

the annual meeting held at Atlanta on February 3 and 4, 1925, and it was voted again to apply for recognition as a branch.

COTTON STATES BRANCH.—The application of the Association of Cotton States Entomologists received the attention of the American Association of Economic Entomologists on December 31, 1925, at Kansas City, Mo. At that time the application was accepted and the Association of Cotton States Entomologists became a branch of the American Association of Economic Entomologists, to be known as the Cotton States Branch, with territory to include North Carolina, Tennessee, Arkansas, Oklahoma, and Texas, and all States south thereof.

The first meeting of the organization after it became a branch of the American Association of Economic Entomologists was held at Atlanta on February 3 and 4, 1926, with W. E. Hinds, chairman, and G. M. Bentley, secretary. It is of interest to note that the late Dr. Hinds was serving as chairman when the Branch was organized and as president when the organization affiliated with the Association of Southern Agricultural Workers. As a matter of fact, the records show that Dr. Hinds served as president during the long period from 1911 to 1926. The organization has had only four secretaries since 1911, A. F. Conradi from 1911 to 1924, G. M. Bentley from 1924 to 1927, Oliver I. Snapp from 1927 to 1939, and John T. Creighton since 1939.

The second meeting of the Branch was also held at Atlanta on February 2, and 3 1927, with Franklin Sherman, chairman, and G. M. Bentley, secretary. Then followed two meetings of the Branch within a period of 2 months, one at Nashville, Tenn., on December 29, 1927, which was held jointly with the American Association of Economic Entomologists, and one at Memphis, Tenn., on February 1 and 2, 1928. The Cotton States Branch sponsored the annual meeting of the parent Association in Nashville in 1927 and provided the annual entomologists' dinner and entertainment for that meeting. G. M. Bentley and Oliver I. Snapp served as chairman and secretary-treasurer, respectively, for these two meetings.

The fourth annual meeting of the Cotton States Branch was held at Houston, Texas, on February 6 and 7, 1929, with a total attendance of 71. This was the first meeting of the Branch held west of the Mississippi. The Texas Entomological Society arranged for the dinner and an extension of this meeting was an excursion to the Lower Rio Grande Valley to see phases of work on the Mexican fruit worm, border inspection, and other entomological problems. Officers were F. L. Thomas, chairman, J. W. Folsom, vice chairman, and Oliver I. Snapp, secretary-treasurer.

It was voted at this meeting that the annual dues in the Cotton States Branch should be one dollar.

The fifth annual meeting of the Branch was held at Jackson, Miss., on February 6 and 7, 1930, with an attendance of 92. B. R. Coad was chairman, R. W. Harned vice chairman, and Oliver I. Snapp secretary-treasurer. This meeting was concluded with a tour to the Delta laboratory at Tallulah, La., on February 8. At the annual meeting was held at Memphis, Tenn., on February 1, 1934, with R. W. Leiby, chairman, S. W. Bilsing, vice chairman, and Oliver I. Snapp, secretary-treasurer. One of the most interesting and instructive meetings of the Branch was the tenth annual meeting held in Atlanta, Ga., on January 31 and February 1, 1935, with S. W. Bilsing, chairman, S. Marcovitch, vice chairman, and Oliver I. Snapp, secretary-treasurer.

FIG. 3.—Members of the Cotton States Branch in annual session at New Orleans, La., Feb. 3-5, 1938.

sixth annual meeting of the Branch in Atlanta, Ga., on February 5 and 6, 1931, it was voted that the executive committee should consist of the three elected officers and the two preceding chairmen, and that the secretary should be elected for a 3-year period. Officers were J. M. Robinson, chairman, S. W. Bilsing, vice chairman, and Oliver I. Snapp, secretary-treasurer.

The Branch held a joint meeting with the American Association of Economic Entomologists in New Orleans, La., on December 31, 1931, followed by the regular seventh annual meeting in Birmingham, Ala., on February 3, 1932, with R. W. Harned, chairman, Herbert Spencer, vice chairman, and Oliver I. Snapp, secretary-treasurer. The annual entomologists' dinner and entertainment at New Orleans was provided by the Branch, which also arranged the program for the joint meeting. The eighth annual meeting was held at New Orleans on February 2 and 3, 1933, with J. W. Folsom, chairman, R. W. Leiby, vice chiarman, and Oliver I. Snapp, secretary-treasurer. The ninth

In order to make the meetings of the Cotton States Branch more accessible to entomologists in Texas and Oklahoma, it was voted at the eleventh annual meeting, held in Jackson, Miss., on February 5 and 6, 1936, that future meetings of the Branch shall be held annually in the following order: West of Mississippi, on the Mississipi, east of the Mississippi, and on the Mississippi. It was also voted that whenever possible the meeting be held in conjunction with the Association of Southern Agricultural Workers. Officers at that time were Clay Lyle, chairman, R. C. Gaines, vice chairman, and Oliver I. Snapp, secretary-treasurer.

In compliance with the schedule of meetings adopted in 1936, the twelfth annual meeting of the Branch was held at San Antonio, Texas, on February 18, 19, and 20, 1937, with the Texas Entomological Society. This was the first meeting since 1920 that was not held as a sectional part of the Association of Southern Agricultural Workers. The attendance of 113 was larger than that of any previous

meeting. Officers were W. E. Anderson, chairman, W. E. Dove, vice chairman, and Oliver I. Snapp, secretary-treasurer.

One hundred and fifty attended the thirteenth annual meeting of the Branch in New Orleans on February 3, 4, and 5, 1938. The growth of the Branch is indicated by comparing figure 3 with figures 1 and 2. The sessions on February 4 were held jointly with the Louisiana Entomologists, a branch of the Louisiana Academy of Science. A special feature of this meeting was a trip to the sulfur wells south of New Orleans.

The fourteenth annual meeting of the Branch was held in conjunction with the fourth annual Florida Entomological Congress at Tampa on February 21, 22, and 23, 1939, with C. O. Eddy, chairman, W. G. Bruce, vice chairman, and Oliver I. Snapp, secretary-treasurer. The attendance of 166 at this meeting was greater than that of any previous meeting of the Branch, and it was undoubtedly one of the best meetings in the history of the organization. There were a number of unique features provided for this meeting that included a central Florida tour by bus, special program for ladies, Cotton States Entomologists' trophy race, and other entertainment.

This history of an organization of entomologists during the last 36 years is but a reflection of the progress that entomology has made in the southern territory during this period.—6-6-40.

Control of the Pink Bollworm with Insecticides

A. J. CHAPMAN and W. L. LOWRY, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Little has been published on insecticides for the control of the pink bollworm, *Pectinophora gossypiella* (Saund.). Nevertheless, considerable research has been conducted on insecticidal control, and many unpublished reports have been prepared by various workers in the Bureau of Entomology and Plant Quarantine of the United States Department of Agriculture. Investigations on insecticides were begun soon after the pink bollworm was discovered in the United States, more than 20 years ago.

The biological habits of this insect make it difficult to control. A great many of the eggs are laid under the bracts of the bolls, where they are well protected from insecticides. The entire feeding period of the larvae is spent within the bolls or squares safe from the action of insecticides. There is an overlapping of generations, with no distinct broods or peaks of larval abundance, and, since protection is needed throughout the season, a long period of applications will be necessary. Furthermore, the bolls and squares are well protected by the foliage, and adequate coverage is difficult. The importance of the pink bollworm as a pest of cotton justifies continuing investigations, however, since an insecticide that could be used in eradication or repression programs, although not practical for general use, would be of great benefit in eradicating isolated infestations or preventing spread to new areas.

The earliest insecticidal experiments directed against the pink bollworm on the North American Continent were a series of tests conducted in the Laguna district of Mexico during the period 1918–22 by Loftin *et al.* (1921) and Ohlendorf (1926) at the laboratories maintained by the United States Department of Agriculture in cooperation with the Mexican Department of Agriculture. These tests were confined chiefly to dusting with arsenicals, including lead arsenate, calcium arsenate, zinc arsenate, and perhaps others, for control of the larvae and moths. Although no outstanding results were obtained, the degree of control was sufficiently encouraging to warrant further investigations.

Work was continued in Mexico during the period 1929 to 1936 by C. S. Rude, who tested sodium fluosilicate, nicotine sulfate, calcium cyanide, sulfur, and calcium arsenate in field plots. Sodium fluosilicate and nicotine sulfate each showed some degree of control, but the results were not conclusive.

In 1927, after the pink bollworm had become established in the Big Bend of Texas, the Bureau of Entomology in cooperation with the Bureau of Agricultural Engineering of the United States Department of Agriculture and the Texas Agricultural Experiment Station, established a pink bollworm research station at Presidio. Each season from 1933 to 1940 insecticidal tests have been conducted in the Presidio Valley, formerly under the direction of F. A. Fenton and later under the superivison of A. J. Chapman. Field, cage, and laboratory methods of experimentation have been employed in the testing of a number of those insecticides which seemed most likely to be successful against the insect.

Among the materials tested were calcium arsenate, lead arsenate, paris green, copper arsenite, copper carbonate, bordeaux mixture, basic copper arsenate, derris, cubé, pyrethrum, nicotine sulfate, fixed nicotines, phenothiazine, sulfur, cuprous cyanide, oils, sodium fluosilicate, barium fluosilicate, cryolites, and others. In addition, a number of materials were tested as soil fumigants against the overwintering larvae.

These insecticides were applied either as dusts or as sprays and most of them were used with and without diluents. Some were used in combination with others or with materials not listed above. When tested in the field a regular 4-day schedule of applications was adhered to insofar as practicable, and an attempt was made to obtain the best possible plant coverage. In general, many of these materials have some control, but the results have not been very significant. The most important thing was the elimination of those insecticides which proved ineffective and the selection of those which gave the best and most consistent results for further study. The latter were principally the fluorine compounds and fixed nicotines. Among the materials that were disappointing may be mentioned derris. In laboratory tests in 1933 derris dust gave 72 to 100 per cent mortality of larvae that came in contact with the material. Poor control was obtained in the field, and subsequent tests showed that derris after exposure to direct sun rays did not give significant reductions and after exposure in the shade lost some of its effectiveness.

Conditions in the Presidio Valley are unfavorable for field-plot work. The restricted acreage planted to cotton is a barrier to the choice and location of fields suitable for experimental work. The soil is not uniform or level, and the fields are divided into narrow strips for irrigation. The presence of Texas root rot causes the cotton to die prematurely in irregular shaped areas. The application of irrigation water, especially in the heavy soils, prevents entrance into the fields for several days at a time and interferes with the poisoning schedule. Damage to cotton by bollworms, leaf worms, stink bugs, and other insects affects the results. In 1940 a heavy rainfall and hail in May necessitated considerable replanting and resulted in uneven stands and retarded development of the crop.

During 1940 the investigations on insecticidal control of the pink bollworm were continued by the writer at the Presidio laboratory. Inasmuch as experimentation over a period of several years had shown that arsenicals were not very effective, more attention was given to fluorine insecticides and ovicides. Results in the field were based on average reduction in larvae per boll in the treated plots over that in untreated or check plots. Three field tests in which cryolite containing approximately 33 per cent of sodium fluoaluminate was used showed average reductions in larvae per boll of 19.7 per cent, 24.6 per cent, and 44.8 per cent. These results were significant mainly in that this insecticide showed essentially the same results as had been obtained in previous years. The fact that conditions under which these tests were conducted have varied from year to year makes it difficult to illustrate graphically the similarity of results obtained over a period of years. Perhaps it will suffice to say that of the materials thus far tested against the larvae the fluorine compounds, particularly cryolite, have given the best and most consistent results.

During the past season cryolite dust containing approximately 85 per cent of sodium fluoaluminate, basic copper arsenate dust, cuprous cyanide dust, and a cryolite-oil spray (50 pounds of cryolite, 50 gallons of light oil, and 50 gallons of water) were tested in a randomized-block arrangement. Six applications of each insecticide were made at 4-day intervals. Basic copper arsenate caused 28.4 per cent reduction in larvae per boll, cuprous

cyanide 47.7 per cent, cryolite 53.4 per cent, and cryolite-oil spray 59.6 per cent. Here again the cryolite dust and cryolite-oil spray showed the highest control

Other insecticidal studies carried on in 1940 were a series of laboratory tests designed to evaluate the ovicidal effect of certain sprays against the pink bollworm. A number of preliminary laboratory tests were conducted in which nicotine sulfate and light petroleum oils were used alone and combined in various proportions with and without emulsifiers. These materials were largely modifications or adaptations of spray formulas used successfully as ovicides in codling moth control.

Several thousand pink bollworm eggs were used in the tests, and the results were based on the number of eggs hatching in the treated group as compared with that in the untreated or check group. Prior to treatment separate lots of green bolls that had been previously placed in breeding cages and exposed to oviposition were collected daily over a period of 4 days. In some of the tests the bracts or involucres were removed and the calyx was tuned back to expose the eggs; in others the eggs were either removed and placed on blotting paper in petri dishes or allowed to remain undisturbed on the boll. The ovicides were applied as sprays or the bolls were dipped in the solution.

The data obtained indicated that the older eggs were slightly more susceptible to the ovicides than freshly laid eggs, especially when nicotine sulfate was used. Both nicotine sulfate and petroleum oils showed some ovicidal value when used alone, but in all cases were more effective when combined. Reductions in hatch for the different treatments, as calculated by Abbott's formula, ranged from 7.8 to 97.3 per cent. The most effective treatment was a spray composed of 2 pints of 40-per cent nicotine sulfate to 50 gallons of miscible oil and 50 gallons of water. Three combinations of a light petroleum oil, nicotine sulfate, an emulsifier, and water caused reductions in hatch of 72.3 per cent, 85.4 per cent, and 91.1 per cent.

CONCLUSION.—In conclusion, it may be said that the work on insecticidal control of the pink bollworm in the past has laid a foundation on which to build in the future. Considerable reductions in larval populations have been obtained from fluorine compounds applied as sprays or dusts. The results from ovicides in laboratory tests suggest further investigations along this line, Much remains to be done in the testing of insecticides or combinations of insecticides for use against the eggs or young larvae and in the development of a technique of application for field use, but the results from preceding tests lend encouragement to future investigations.—2-7-41.

LITERATURE CITED

Loftin, U. C., K. B. McKinney, and W. K. Hanson. 1921. Report on investigations of the pink bollworm of cotton in Mexico. U. S. Dept. Agr. Dept. Bul. **918.**

Ohlendorf, W. 1926. Studies of the pink bollworm in Mexico. U. S. Dept. Agr. Dept. Bul. **1374.**

NIGHT INSPECTION FOR VESSELS FROM HAWAII

"To aid emergency shipping needs, plant-quarantine inspection for vessels arriving at mainland ports from Hawaii has been made possible during night as well as daylight hours, by a revision of Regulation 8 of Quarantine No. 13, according to a press notice of the Department of Agriculture on May 13, 1941. Heretofore boarding and inspection of these vessels at mainland ports was from sunrise to sunset, primarily because of the additional load which night inspection placed on a limited personnel. Under the revised regulation, it will be possible to arrange for inspection between sunset and sunrise, provided the inspection service is notified sufficiently in advance, so that the required number of inspectors can be notified and assigned to this special duty. Thorough inspection of vessels arriving from Hawaii is to prevent establishment in mainland fruit areas of the Mediterranean fruitfly and the melonfly, both of which are found in Hawaii. In this inspection the vessel itself, its cargo, and passengers' baggage are carefully examined to prevent the landing of any fruits or vegetables which might carry these pests from Hawaii. The frequent discovery in these vessels of Hawaiian products carrying these live insects emphasizes the importance of this inspection.

Factors Influencing the Formation of Resting Pink Bollworm Larvae

A. J. Chapman and M. H. Hughs, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

The pink bollworm, *Pectinophora gossypiella* (Saund.), passes the winter in the larval stage. These overwintering worms are commonly referred to as "resting" or "long-cycle" larvae to distinguish them from the "short-cycle" type occurring during the crop-growing season and pupating within a few days after completion of feeding. Most of the resting larvae pass the winter in the cotton bolls, in which they developed. Some of them, however, on completion of feeding cut their way out of the bolls and spin cocoons in the soil or in the debris on the soil surface, where they spend the winter.

Tests were conducted at Presidio, Texas, to determine some of the factors conducive to the development of resting larvae. These tests involved larvae over-wintering in bolls as well as larvae over-wintering in cocoons in the soil or on the surface of the soil.

Formation of Resting Larvae in Bolls of Different Ages.—The primary purpose of these tests was to determine to what extent the age of the boll in which the worms feed influences the formation of resting larvae.

Screen-wire cages were placed over cotton plants early in the season, and the blooms were tagged daily so that the exact age of the bolls would be known. Bolls 20, 30, and 40 days old were artificially infested by placing under the calyx pink bollworm eggs that were about ready to hatch. The infested bolls were left on the plants until they had opened and dried out and were then collected and stored for later examination to determine the number of resting larvae in bolls of the three age groups. Throughout the tests the plants were given sufficient water to keep them in a vigorous growing condition and prevent any premature opening of the bolls. The first series of egg installations were made between August 2 and September 3 and the second series between September 22 and October 1. The results for the two series are shown in table 1.

The results indicate that the age of the boll is an important factor in the development of resting larvae. This is in agreement with the reported findings of other investigators working under tropical conditions (Taylor 1936, Squire 1937, and Fife[1]). Higher percentages of resting larvae were recovered from the 20- and 30-day-old bolls infested from September 22 to October 1 than from bolls of the same ages infested from August 2 to September 3 probably because of lower temperatures.

Table 1.—Formation of resting pink bollworm larvae in bolls of different ages, Presidio, Texas, 1940.

Age of Bolls, Days	Number of Bolls	Number Exit Holes	Number of Larvae Recovered	Percentage of Larvae Recovered
Bolls Infested Between August 2 and September 3				
20	43	60	9	13.04
30	36	40	15	27.27
40	44	3	49	94.23
Bolls Infested Between September 22 and October 1				
20	42	20	7	25.93
30	59	37	28	43.07
40	24	2	17	89.47

Influence of Temperature and Soil Moisture on the Formation of Resting Larvae in Cocoons.—Tests were designed with the view of determining the influence of temperature and soil moisture on the development of resting larvae overwintering in cocoons. Heavily infested green bolls were collected in the field and placed in a tray with a screen-wire bottom. At intervals of 3 or 4 days the bolls were removed and replaced by fresh green bolls. Larvae upon reaching maturity emerged from the bolls and dropped into a tub under the tray. Each day the worms were collected from the tub and released in two screen-wire cages set over cotton plants in the field. The cages were open at the top and bottom. At the time the cages were set, all fruiting forms were removed from the plants so that no larvae would enter the cages other than those released. The soil under one of the cages was irri-

[1] Unpublished manuscript by L. C. Fife.

gated just before worm releases were begun and that under the other cage was left dry. Each day the periods September 1 to 15, September 16 to 30, October 1 to 15, and October 16 to 30, 50 pink bollworm larvae were released in each cage, or a total of 750 larvae per cage in irrigated soil and 750 in nonirrigated soil during each period.

On December 6, 36 days after the final worm releases were made, the soil under each cage was examined and the number of resting larvae recorded. The results of these tests are shown in table 2.

Table 2.—Resting larvae recovered in irrigated and nonirrigated soil where pink bollworms had been released at various periods in the fall, Presidio, Tex., 1939.

Release Period[1]	Number of Larvae Recovered			Percentage of Total Larvae Recovered	Temperature, Degrees F.			Rainfall, Inches
	Irrigated Soil	Non-irrigated Soil	Total		Maximum	Minimum	Mean	
Sept. 1–15	9	17	26	1.73	102	60	82.20	0.12
Sept. 16–30	193	277	470	31.33	100	46	75.57	.00
Oct. 1–15	409	413	822	54.80	100	42	71.60	.25
Oct. 16–30	491	511	1002	66.80	91	43	68.13	.10
Total	1,102	1,218	2,320	—				

[1] A total of 1,500 larvae were released during each period, 750 over irrigated soil and 750 over nonirrigated soil.

As shown in table 2, the number of resting larvae increased as the season advanced and the temperatures became less favorable for the insect's development. Only a few resting worms were recovered from the September 1 to 15 release, but there was a distinct increase in worms recovered from the releases made after the middle of September.

The proportion of worms going into the resting stage during the different periods would undoubtedly fluctuate from year to year, depending on seasonal conditions, but these tests indicate that temperature is an important factor in the development of resting larvae.

In the September releases a significantly higher number of resting larvae was recovered from the cages over dry soil than from the cages over irrigated soil, but in the October releases there was no significant difference between the numbers of resting larvae recovered from cages over dry soil and from cages over irrigated soil. These results would indicate that during September the additional moisture in the soil tended to cause the worms to pupate. During October the temperatures were lower, and the additional moisture in the soil did not stimulate an increase in pupation.

These experiments are of practical significance in that they show the importance of early maturity of the cotton crop combined with early field clean-up, in areas where practicable, in reducing the number of pink bollworms entering the resting stage.—2-7-41.

Literature Cited

Taylor, T. H. C. 1936. Report on a year's investigation of *Platyedra gossypiella* (pink boll worm) in Uganda (March, 1935 to April, 1936). Uganda Dept. Agr. Ann. Rpt. 1936, pt. 2: 19–33.

Squire, F. A. 1937. A theory of diapause in *Platyedra gossypiella* Saund. Trop. Agr. [Trinidad] **14**(10): 299–301.

The potato tuber moth is the subject of a quarantine placed by the Kansas Entomological Commission effective May 31, 1941, against California, Texas, Louisiana, and Hawaii. Provision is made for entry of potatoes on inspection or on fumigation under one of five designated formulas.

The State of Wisconsin passed a bill in the 1941 session of the legislature creating a new statute prohibiting the shipment into or within the State of living insects in any stage of their development, or any living plant pathogens, as such, without a permit from the State Department of Agriculture.

Effect of Different Calcium Arsenates upon Boll Weevils, Cotton Aphids, and Plant Bugs, and upon Yields

R. C. Gaines, M. T. Young, and G. L. Garrison, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

Experiments in the control of the boll weevil, *Anthonomus grandis* Boh., with calcium arsenates containing various percentages of water-soluble arsenic pentoxide were begun at several localities in 1938. The results of two seasons' work with calcium arsenates in which these percentages were 0.5, 4.6, and 10.3 have been reported (R. C. Gaines 1939, 1940). In 1939 records were also obtained of cotton aphid, *Aphis gossypii* Glov., populations in the various plots at Tallulah, Louisiana (Gaines, *et al.*, 1940). In 1940, experiments were continued at Tallulah with calcium arsenates containing 0.42, 11.4, and 16.5 per cent water-soluble arsenic pentoxide, as determined by the New York method, and having average particle sizes of 1.0, 1.3, and 3.1 microns, respectively, as measured by the air-permeation method (Gooden & Smith 1940). The last calcium arsenate was specially prepared.

Plots.—Each plot, including buffer areas, was 10 rows in width and of sufficient length to be one-eighteenth of an acre in area. The buffer areas in each plot consisted of 3 rows on each side and an area $3\frac{1}{2}$ feet wide across each end. All records, except those of insecticide applications, were made within the buffers on the 4 middle rows, the area in each plot being one-fiftieth of an acre. Insecticide applications were made on the entire plot. The plots were arranged in randomized blocks. There were 4 replicate blocks in each of 2 fields, making a total of 8 replications of each of the 4 treatments. The fields are designated as experiments IX and IXA.

Treatments.—The quantity of calcium arsenate applied to a plot was obtained by weighing the single-nozzle rotary hand guns before and after an application. Calcium arsenate treatments were started in experiment IX on July 26 and continued until August 21, and in experiment IXA they were begun on August 3 and continued until August 30. In each experiment five effective applications were made during the early morning at as near as possible 5-day intervals.

Records.—All infestation records were started after the first calcium arsenate applications were made and were continued at approximately 7-day intervals. Boll weevil infestations were determined by examining 100 squares on consecutive plants beginning on a different row at each end of each plot, making a total of 200 per plot for each record, the records being continued as long as sufficient squares were available. All punctured squares, both egg and feeding punctures, were recorded. Three such records were made in each of the fields. The cotton aphids were counted on 1 square inch of leaf area near the center of the fourth leaf from the top on 50 consecutive plants, beginning on a different row at each end of each plot, making a total of 100 leaves or square inches per plot for each record. Five such records were made in experiment IX and four in experiment IXA. Tarnished plant bug, *Lygus pratensis oblineatus* (Say), and rapid plant bug, *Adelphocoris rapidus* (Say), adults and nymphs observed during the examination for boll weevil punctures were recorded. Three such records were made in each experiment. The records for each insect in each experiment were averaged to obtain the mean infestation during the period of treatment. Yield was the amount of seed cotton picked from one-fiftieth of an acre in each plot.

In addition to the field data cage tests were made to compare the mortalities of boll weevils caused by the three calcium arsenates.

Results.—Table 1 presents a summary of records made in experiments IX and IXA, and table 2 the analyses of variance of these data. In the combined analyses the interaction of treatments and fields was greater than within-field error for all records, except those of tarnished

[1] The authors were assisted in the field plots by G. D. Green, G. H. Rainwater, J. E. Gillaspy, and W. A. Lee. The cage records were made by G. L. Smith, A. L. Scales, J. A. Fontenot, G. C. Woodruff, and B. M. Tyner. All chemical analyses and particle-size determinations were furnished by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Table 1.—Average infestation of boll weevils, cotton aphids, tarnished and rapid plant bugs, and average yield of seed cotton, following treatment with calcium arsenates differing in arsenic pentoxide content, with statistical analyses, Tallulah, La., 1940.

Experiment and Calcium Arsenate Used	Calcium Arsenate, Pounds per Acre	Boll Weevil Infestations		Aphids per Square Inch of Leaf	Tarnished Plant Bugs per 200 Squares		Rapid Plant Bugs per 200 Squares		Yield of Seed Cotton, Pounds per Plot
		Per Cent Squares Punctured	Equivalent angles		Adults	Nymphs	Adults	Nymphs	
Experiment IX:									
Untreated check	—	26.9	31.0	2.23	0.9	4.6	0.7	3.6	24.06
Calcium arsenate:[1]									
0.42% As_2O_5	6.5	11.9	19.9	2.32	.9	2.9	.4	2.8	27.19
11.4% As_2O_5	6.4	12.8	20.6	4.47	.6	1.9	.6	2.6	25.93
16.5% As_2O_5	7.7	13.1	19.4	5.17	.3	1.1	.3	.6	26.07
Minimum significant difference:									
At 5% level	—	11.3	—	—	—	2.4	—	1.4	—
At 1% level	—	16.2	—	—	—	3.4	—	2.0	—
Experiment IXA:									
Untreated check	—	53.1	46.8	3.27	2.4	8.7	0.3	0.5	18.06
Calcium arsenate:[1]									
0.42% As_2O_5	6.0	46.0	42.7	5.39	2.1	11.3	.2	.5	24.47
11.4% As_2O_5	6.5	35.4	36.4	6.66	1.1	6.2	.0	.3	24.97
16.5% As_2O_5	7.6	37.1	37.5	6.36	1.3	3.9	.1	.6	25.94
Minimum significant difference:									
At 5% level	—	7.5	4.5	1.05	—	4.7	—	—	2.9
At 1% level	—	10.8	6.4	1.51	—	6.7	—	—	4.1

[1] Percentages refer to water-soluble arsenic pentoxide as determined by the New York method.

and rapid plant bug adults. The interaction of treatments and fields was significant in the case of rapid plant bug nymphs and yields. Since this interaction for some of the records indicated that the treatments reacted differently in the two experiments, it was deemed advisable to discuss the records in each experiment rather than the combined records.

In experiment IX there was a much lighter boll weevil infestation than in experiment IXA. Aphids and tarnished plant bug adults and nymphs were somewhat more numerous in experiment IXA, but rapid plant bug adults and nymphs were more numerous in experiment IX. The cotton was planted much later in experiment IXA than in experiment IX.

Table 2.—Analyses of variance of data from experiments IX and IXA (table 1).

Source of Variation	Degrees of Freedom	Mean Square Pertaining to—							
		Boll Weevil Infestations		Aphids per Square Inch of Leaf	Tarnished Plant Bugs per 200 Squares		Rapid Plant Bugs per 200 Squares		Yield of Seed Cotton, Pounds per Plot
		Per Cent Squares Punctured	Equivalent Angles		Adults	Nymphs	Adults	Nymphs	
Experiment IX:									
Blocks	3	149.24	99.80	1.63	0.22	3.46	0.39	2.60	43.66
Treatments	3	205.82*	123.53	8.97	.31	9.20*	.09	6.77†	6.74
Error	9	49.93	34.90	2.96	.31	2.23	.12	.78	4.50
Experiment IXA:									
Blocks	3	38.50	13.65	1.71	1.08	12.22	0.05	0.36	32.40
Treatments	3	271.74†	92.64†	9.43†	1.46	40.82*	.05	.09	51.35†
Error	9	22.00	7.81	.43	1.31	8.46	.07	.08	3.25

* Significant. † Highly significant.

The calcium arsenate applications were followed by significant differences in both boll weevil and cotton aphid infestations in experiment IXA and nonsignificant differences in experiment IX. The calcium arsenates failed to cause significant differences in either tarnished or rapid plant bug adults in both experiments, but caused significant differences in tarnished plant bug nymphs in both experiments and in rapid plant bug nymphs in experiment IX. There were no significant differences in yield in experiment IX, while the differences in yield were highly significant in experiment IXA. In both experiments the infestation records indicated that the three calcium arsenates were equally effective against boll weevils. In both experiments the calcium arsenates containing 16.5 and 11.4 per cent of water-soluble arsenic pentoxide were followed by greater increases in cotton aphids and greater reductions in tarnished and rapid plant bugs as compared with the checks and the calcium arsenate containing only 0.42 per cent of water-soluble arsenic pentoxide. The yields also indicated that the three calcium arsenates were equally effective. In both experiments the calcium arsenate containing 0.42 per cent of water-soluble arsenic pentoxide caused an average increase over the checks of 239 pounds of seed cotton per acre; the calcium arsenate containing 11.4 per cent, 220 pounds; and the one containing 16.5 per cent, 247 pounds.

J. C. Gaines (1940) found that a special calcium arsenate, containing large particles and a high percentage of water-soluble arsenic pentoxide, gave a significantly better control of the rapid plant bug than did a commercial calcium arsenate. This special calcium arsenate also gave a higher control of the boll weevil and a higher yield than the commercial calcium arsenate, but the differences were not found to be significant.

In the boll weevil mortality tests the calcium arsenate containing 0.42 per cent of water-soluble arsenic pentoxide gave a net mortality of 48.2 per cent; the calcium arsenate containing 11.4 per cent a mortality of 73.2 per cent; and that containing 16.5 per cent, a mortality of 72.6 per cent. The minimum significant difference at the 5 per cent level was 11.9 per cent, and at the 1 per cent level, 15.6 per cent.

SUMMARY.—Experiments were conducted in two fields to study the effect of calcium arsenates containing different percentages (0.42, 11.4, and 16.5 per cent) of water-soluble arsenic pentoxide upon the boll weevil, the cotton aphid, the tarnished plant bug, and the rapid plant bug, and upon the yield of seed cotton, and the results were analyzed statistically. In both experiments the infestation records indicated that the three calcium arsenates were equally effective against the boll weevil. In both experiments the calcium arsenates containing 16.5 and 11.4 per cent of water-soluble arsenic pentoxide were followed by greater increases in cotton aphids and greater reductions in the tarnished plant bug and the rapid plant bug as compared with the checks and the calcium arsenate containing only 0.42 per cent of water-soluble arsenic pentoxide. The yields in each experiment also indicated that the three calcium arsenates were equally effective. In both experiments the calcium arsenate containing 0.42 per cent of water-soluble arsenic pentoxide caused an average increase over the checks of 239 pounds of seed cotton per acre; the one containing 11.4 per cent, 220 pounds; and the one containing 16.5 per cent, 247 pounds.—2-13-41.

LITERATURE CITED

Gaines, J. C. 1940. Tests of insecticides for certain cotton insects during 1939. JOUR. ECON. ENT. **33**(4): 684–8

Gaines, R. C. 1939. Boll weevil control tests with calcium arsenates containing different percentages of water-soluble arsenic pentoxide. JOUR. ECON. ENT. **32**(6): 794–7.

Gaines, R. C. 1940. Boll weevil control with calcium arsenates containing different percentages of water-soluble arsenic pentoxide. JOUR. ECON. ENT. **33**(4): 682–4.

Gaines, R. C., M. T. Young, and G. L. Smith. 1940. Effect of insecticides used in boll weevil control upon aphids and mirids. JOUR. ECON. ENT. **33**(5): 792–6.

Gooden, E. L., and C. M. Smith. 1940. Measuring average particle diameter of powders and air-permeation apparatus. Ind. & Eng. Chem., Analyt. Ed. **12**(8): 479–82.

Spraying Versus Dusting for Boll Weevil Control

K. P. Ewing, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

There has been an increased demand lately for more definite information regarding the relative effectiveness of insecticides applied as dusts and as sprays in controlling cotton insects. In central Texas unfavorable conditions for dusting, such as high winds and no dews, sometimes prevail during a considerable portion of the period when the insects cause critical damage and when control measures should be used. Needless to say, when unfavorable dusting conditions are prolonged, the cotton farmer would welcome a spraying program, provided the insects could be economically controlled by spraying. Furthermore improved spray machinery for use on cotton has become available recently and is now being sold to farmers. This paper reports experiments conducted in 1939 and 1940 about 25 miles east of Waco in Limestone County.[1]

Plots and Insecticides.—In 1939 tests were made with calcium arsenate dust and lead arsenate spray. There were three replicates, each in a separate cotton field. The plots in the three replicates ranged in size from 1.6 to 2.66 acres. They were each 30 rows wide and extended the full length of the field.

In 1940 treatments were made with calcium arsenate dust, calcium arsenate spray, and lead arsenate spray. There were three replicates, each in a different field. In two fields the plots were 24 rows wide and in the third 32 rows wide. The plots ranged in size from 1.47 to 1.98 acres. The calcium arsenate contained 0.75 per cent of water-soluble arsenic pentoxide by the New York method and 40.1 per cent of total arsenic pentoxide. The lead arsenate contained 0.18 per cent of water-soluble arsenic pentoxide by the A.O.A.C. method and 31.1 per cent of total arsenic pentoxide. Both materials had a mean surface particle diameter of less than 1 micron, as determined by air permeation.

Dusting and Spray Machines.—The dust was applied with single-nozzle, rotary-type hand dusters. The spray applications were made with a four-row, high pressure, tractor-drawn sprayer with three nozzles per row. The adjustable nozzles were so arranged that one sprayed downward from an elevation of 2 to 6 inches above the tip of the plant and one sprayed upward on each side of the cotton row. The pressure was kept at about 300 pounds. All parts of the plants were thoroughly covered with an atomized mist.

Poison Applications.—In 1939 the lead arsenate spray was applied at the rate of approximately 100 gallons per acre, whereas in 1940 the dosage was reduced to 60 gallons per acre. The 60-gallon dosage gave thorough coverage, even in the largest cotton, without loss from excess material dripping off the plants, as was sometimes the case when 100 gallons were used.

When possible the spray and dust treatments were made on the same day, the dust being applied during the early morning and the spray later in the day. In 1939 three effective applications of each insecticide were made between July 1 and July 27 and in 1940 five applications were made between July 9 and July 31.

With the exception of the last application in 1940, the lead arsenate as a spray was applied at the rate of approximately 2.5 pounds per acre and the calcium arsenate in both spray and dust form at the rate of 7 to 8 pounds per acre. In an effort to control the light infestation of bollworms present at the time of the last application in 1940 (July 31), the insecticides were all applied at the rate of 11.3 to 15 pounds per acre.

The reasons for applying the lead arsenate at a lower rate than the calcium arsenate were as follows: During an average year in Texas thousands of farmers spray hundreds of thousands of acres of cotton with 1 to 2.5 pounds of lead arsenate per acre for leaf worm control. It was deemed important to ascertain the value of this leaf worm remedy in controlling the boll weevil. Furthermore, lead arsenate costs nearly twice as much as calcium arsenate, and unless a smaller amount

[1] Claude Nussbaum, Mexia, Tex., cooperated by furnishing the experimental cotton, a power sprayer, all insecticides, and the labor necessary in making the poison applications. The Waco laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, furnished the hand guns used in making the dust applications and the scientific personnel required to make all field-plot records, made recommendations as to when treatment should be made, and supervised the application of the insecticides.

will give approximately as good weevil control as the calcium arsenate under normal conditions, there would be no economy in using lead arsenate.

FIELD-PLOT RECORDS.—Boll weevil infestation records were made at weekly intervals, 600 squares per plot being inspected, 200 near the center and 200 near each end. In 1939 five records were made between June 30 and July 28 and in 1940 five were made between July 8 and August 7. In 1940 three bloom counts were made, on July 25, August 1, and August 7. Counts were made of the white blooms on the five middle rows of each plot. With one exception, yield records were obtained from entire plots, that is, no buffer areas were left between plots or at the ends.

In 1939 root rot killed the cotton in certain areas of one of the fields and therefore only five rows, or 0.46 acre, in each plot in this field were picked. From 1.47 to 2.66 acres per plot were picked in each of the other fields.

RESULTS IN 1939.—The average seasonal infestation of boll weevils in the untreated plots during 1939 was only 18.8 per cent of the squares punctured. With such a light infestation no high gains from control measures could be expected. The average infestation in the plots dusted with calcium arsenate was 11.3 per cent and in the plots sprayed with lead arsenate 15.9 per cent. Although no injurious cotton aphid infestation or any other factor that might have caused a reduction in yield was observed in the plots dusted with calcium arsenate, and although the difference in infestation was in favor of the dusted plots, the sprayed plots produced slightly more cotton than the dusted plots. In the sprayed plots the average gain was 155 pounds of seed cotton per acre, or 30 per cent, and in the dusted plots 31 pounds, or 6 per cent. The check plots averaged 516 pounds of seed cotton per acre.

RESULTS IN 1940.—All experimental fields in 1940 had a high boll weevil infestation. The peak infestations in the check plots of the three fields ranged from 61 to 79 per cent. Conditions therefore were favorable for testing the efficacy of the different poisons in controlling the weevil.

There was no injury in any of the fields from cotton flea hoppers or cotton aphids. Toward the latter part of the season a few bollworms were present. The average infestation of bollwarms after the different treatments is shown by the following percentages of injured forms: Check 9.1, calcium arsenate dust 7.6, calcium arsenate spray 9.7, and lead arsenate spray 10.6. Since these records show only slight differences in injured forms between the check and treated plots (not more than 1.5 per cent) it is believed that the differences in yields were not significantly affected by the bollworm.

Average weekly infestation records made in the different treatments are shown in figure 1. A summary of infestation records, bloom counts, and yield records made throughout the season are given in table 1.

Table 1.—Average seasonal records for the three experimental fields in tests against the boll weevil, Mexia, Tex., 1940.

TREATMENT	PUNCTURED SQUARES, PER CENT	BLOOMS PER ACRE, NUMBER	GAIN IN SEED COTTON PER ACRE[1]	
			POUNDS	PER CENT
Calcium arsenate dust	8.7	4,449	292.7	83.2
Calcium arsenate spray	32.5	2,294	70.3	20.0
Lead arsenate spray	42.1	1,647	5.7	1.6
Check	55.4	1,153	—	—

[1] The average production in the three check plots was 352 pounds per acre.

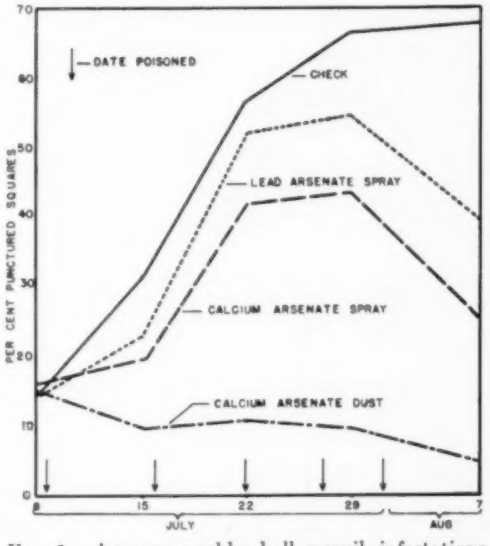


FIG. 1.—Average weekly boll weevil infestations following the different treatments, Waco, Tex., 1940.

All field-plot records show that calcium arsenate applied as a dust gave much better control of the boll weevil and resulted in greater profits than calcium arsenate or lead arsenate applied as a spray.

SUMMARY.—In tests conducted at Waco, Tex., in 1939 and 1940 a power sprayer with three nozzles per row was used in applying calcium arsenate and lead arsenate under 300 pounds' pressure to field cotton in comparison with the standard dust applications for boll weevil control. The plots ranged in size from 1.47 to 2.66 acres. There were three replicates each year, each replicate being in a separate field.

In 1939 when there was a light weevil infestation, the plots sprayed with lead arsenate produced slightly more cotton than those dusted with calcium arsenate.

In 1940, however, under conditions of heavy boll weevil infestation, calcium arsenate dust gave much better weevil control than calcium or lead arsenate spray and resulted in larger gains in seed cotton and greater profits.—2-26-41.

Cryolite and Cryolite-Sulfur Mixtures for Boll Weevil Control and Their Effect on the Cotton Aphid

R. L. MCGARR,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[2]

In tests conducted at State College, Miss., during the season of 1940 synthetic cryolite, alone and in commercial mixtures with sulfur, was compared with calcium arsenate for the control of the boll weevil, *Anthonomus grandis* Boh. and for the effect on the cotton aphid, *Aphis gossypii* Glov.

The treatments were tested in seven randomized blocks located within the same field on the college farm. Each plot

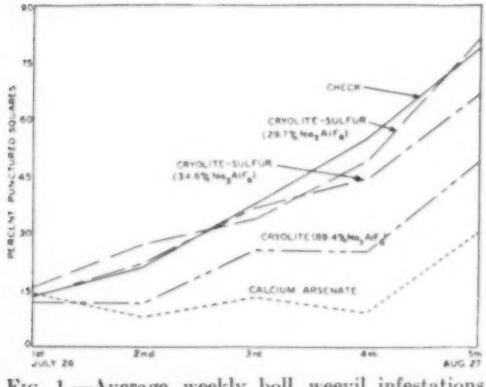


FIG. 1.—Average weekly boll weevil infestations following the different treatments, State College, Miss., 1940.

was 61.5 feet long by 10 rows wide and contained one-twentieth acre. When the cotton was planted, about April 25, 300 pounds of commercial fertilizer was applied per acre. Seven applications of each insecticide were made between July 27 and August 24, 2 of which were washed off by rain within 24 hours and were therefore not considered effective. All insecticides were applied as dusts with a 1-row rotary hand gun early in the morning when the cotton was usually wet with dew and the air for the most part calm.

Infestation counts were taken at about weekly intervals from the four middle rows of each plot. Records on the boll weevil were obtained by examining 100 squares per plot for feeding and egg punctures. One count was made the day before the first dust application, when 12 to 16 per cent of the squares showed punctures and four other counts were made after dusting was begun.

Three records of cotton aphid infestation were taken during the dusting period by counting the aphids per square inch on 100 square inches of leaf area in each plot at each inspection. The fourth leaf from the top of the plants was used for making the counts. No yield records were made in the plots.

The different treatments used and the seasonal boll weevil and aphid infestations following each are shown in table 1.

The average weekly boll weevil infestations in the various plots following each treatment are shown in figure 1.

The cryolite-sulfur mixture containing 29.7 per cent of sodium fluoaluminate gave no control of the boll weevil and

[1] A. W. Faulk, W. R. Smith, and C. A. Wilson assisted in obtaining the field notes and R. C. Gaines made the statistical analyses.

[2] In cooperation with the Mississippi Agricultural Experiment Station and the Mississippi State Plant Board.

Table 1.—Boll weevil infestations and cotton aphid populations following the various treatments. State College, Miss., 1940.

Treatment	Sodium Fluoaluminate, Per Cent	Average Dosage per Acre, Pounds	Average Seasonal Boll Weevil Infestation, Per Cent	Aphids per Square Inch of Leaf Area, Number	
				Maximum	Average
Cryolite and sulfur	29.7	12.1	48.0	1.90	.82
	34.6	11.9	42.5	2.40	1.01
Cryolite	89.4	10.0	27.7	6.33	2.63
Calcium arsenate	—	6.0	15.3	8.97	3.93
Check	—	—	48.4	.64	.37
Significant difference at the 5 per cent level			12.3		.98
Significant difference at the 1 per cent level			16.7		1.32

that containing 34.6 per cent of sodium fluoaluminate gave very little control. The cryolite alone was only about half as effective as calcium arsenate. The increase in aphids where cryolite alone was used approached that where calcium arsenate was used, whereas with the cryolite-sulfur mixtures the aphid populations increased in proportion to the sodium fluoaluminate.—3-3-4.

Effect of Boll Weevil Control and Cotton Aphid Control on Yield as Shown in a Factorial Experiment

R. C. GAINES, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[1]

In 1939 an experiment employing a factorial design was conducted at Tallulah, La., to determine the comparative effect on cotton yield of treatment with calcium arsenate dust for control of the boll weevil, *Anthonomus grandis* Boh., treatment with nicotine dust for control of the cotton aphid, *Aphis gossypii* Glov., and a combination of the two treatments (Gaines *et al.*, 1940). In 1940 similar experiments were made at Tallulah, Florence, S. C., and Waco and College Station, Texas. The experiment at College Station was carried on by the Texas Agricultural Experiment Station.

PLOTS AND TREATMENTS.—Each plot was 10 rows wide and of sufficient length to have an area of one-eighteenth acre, the outer 3 rows on each side and 3.5 feet at each end of the plot constituting buffer areas.

Insecticide applications were made over the entire plot but records of infestations and yield were taken only on the four center rows surrounded by the buffers, or on an area of one-fiftieth acre. Four plots, or one for each treatment, constituted a block, and there were four blocks. In each block the treatments were assigned to the plots at random. Therefore a treatment was replicated four times at each locality and sixteen times in all.

In each block one plot was left untreated to serve as a check, another was dusted with calcium arsenate for boll weevil control, a third was dusted with nicotine dust for cotton aphid control, and the remaining plot was treated with both calcium arsenate and nicotine dust for control of the boll weevil and the cotton aphid.

The calcium arsenate used at all localities was of the same brand and batch. Samples from the three drums used were analyzed in the Division of Insecticide Investigations, of the Bureau of Entomology and Plant Quarantie, and found to contain 7.00, 7.70, and 8.05 per cent of water-soluble arsenic pentoxide (New York method). The nicotine dust was a mixture of nicotine sulfate and lime containing 3 per cent of nicotine.

At each locality calcium arsenate applications were begun when the first blooms appeared on the cotton plants, in order

[1] Records at Florence, S. C., were made by F. F. Bondy, C. F. Rainwater, R. L. Walker, and Minter Dupree; at Tallulah, La., by M. T. Young, G. L. Garrison, G. D. Green, G. H. Rainwater, J. E. Gillaspy, and W. A. Lee; at College Station, Tex., by J. C. Gaines, H. A. Dean, J. C. Barton, and G. C. Menzies and at Waco, Tex., by K. P. Ewing, Abbott Kagan, P. P. Menzies, E. E. Ivy, and T. B. Randolph.

Table 1.—Boll weevil and cotton aphid infestations and yield of cotton, together with analyses of variance, following three insecticidal treatment at four localities in 1940.

Locality and Treatment	Boll Weevil-Punctured Squares, Per Cent	Aphids per Square Inch, Number	Yield per Plot, Pounds
Florence, S. C.:			
(A) Check	2.1	1.47	25.8
(B) Calcium arsenate	.9	5.03	26.1
(C) Nicotine dust	2.7	.85	27.9
(D) Calcium arsenate and nicotine dust	.8	2.72	28.0
Minimum significant difference:			
5% level	—	2.12	—
1% level	—	3.05	—
Tallulah, La.:			
(A) Check	44.5	.60	26.9
(B) Calcium arsenate	24.2	2.79	35.1
(C) Nicotine dust	42.8	.19	26.6
(D) Calcium arsenate and nicotine dust	28.0	.60	39.2
Minimum significant difference:			
5% level	8.3	1.12	2.9
1% level	11.9	1.62	4.1
College Station, Tex.:			
(A) Check	41.3	.09	18.7
(B) Calcium arsenate	16.5	6.88	24.9
(C) Nicotine dust	40.9	.02	16.9
(D) Calcium arsenate and nicotine dust	14.9	.37	26.5
Minimum significant difference:			
5% level	7.2	1.15	4.4
1% level	10.4	1.65	6.3
Waco, Tex.:			
(A) Check	25.4	.04	26.8
(B) Calcium arsenate	13.2	.58	28.4
(C) Nicotine dust	23.8	.06	26.8
(D) Calcium arsenate and nicotine dust	14.4	.11	28.0
Minimum significant difference:			
5% level	—	.09	—
1% level	—	.14	—
All localities:			
(A) Check	28.3	.55	24.5
(B) Calcium arsenate	13.7	3.82	28.6
(C) Nicotine dust	27.5	.28	24.5
(D) Calcium arsenate and nicotine dust	14.5	.95	30.4

Analysis of Variance				
Source of Variation	Degrees of Freedom	Mean Square		
		Boll Weevil	Aphid	Yield
Florence, S. C.:				
Blocks	3	1.59	2.85	22.74
Treatments:				
A & C *vs.* B & D	1	9.30	29.43†	.30
A & B *vs.* C & D	1	.30	8.56	16.00
A & D *vs.* B & C	1	.56	2.91	.04
Total	3	3.39	13.63†	5.45
Error	9	1.84	1.76	23.50
Tallulah, La.:				
Blocks	3	180.05	.29	19.00
Treatments:				
A & C *vs.* B & D	1	1,226.75†	6.84†	432.64†
A & B *vs.* C & D	1	4.31	6.76†	14.82
A & D *vs.* B & C	1	29.98	3.15*	19.80*
Total	3	420.34†	5.58†	155.75†
Error	9	26.78	.49	3.21
College Station, Tex.:				
Blocks	3	7.53	.54	15.42
Treatments:				
A & C *vs.* B & D	1	2,588.27†	50.94†	248.85†
A & B *vs.* C & D	1	4.10	43.26†	.03
A & D *vs.* B & C	1	1.50	41.51†	10.40
Total	3	864.62†	45.24†	86.43†
Error	9	20.36	.52	7.63
Waco, Tex.:				
Blocks	3	29.67	.002	.69
Treatments:				
A & C *vs.* B & D	1	463.33*	.342†	8.27
A & B *vs.* C & D	1	.14	.207†	.23
A & D *vs.* B & C	1	7.79	.235†	.23
Total	3	157.06	.262†	2.91
Error	9	44.48	.004	3.64
All localities:				
Treatments	3	1,020.35	42.87	141.74
Localities	3	3,331.81	16.07	279.33
Treatments×localities	9	141.69†	7.28†	36.27†
Blocks within localities	12	54.71	.92	14.46
Treatments×blocks within localities	36	23.37	.69	9.50

* Significant. † Highly significant.

that at least eight effective applications could be made before the cotton reached maturity. It was thought that eight applications would cause cotton aphids to increase to injurious numbers. The dust was applied with single-nozzle rotary hand guns at an average rate of about 7 pounds per acre. Treatment was made early in the morning and at about 5-day intervals. Eight effective applications were made at Florence, Tallulah, and Waco, whereas eleven were made at College Station. Frequent applications were made to allow differences due to treatment a good chance to develop and be estimated.

Nicotine dust was applied at an average rate of approximately 14 pounds per acre, also with single-nozzle rotary hand guns. Two to four applications were required.

RECORDS.—Boll weevil infestation records were begun after the first calcium arsenate applications were made and were continued as nearly as possible at either 5- or 7-day intervals as long as sufficient squares were present for examination. One hundred squares on consecutive plants in one row at one end and 100 on a different row at the other end of each plot were examined for each record. From the squares examined all those containing egg or feeding punctures were recorded. Four records were made at Florence, six at Tallulah, seven at College Station, and four at Waco. At each locality the records for each plot were averaged to obtain the mean infestation during the period of treatment.

Cotton aphid counts were also begun after the first calcium arsenate applications were made and were continued as nearly as possible at either 5- or 7-day intervals. Counts were made on 1 square

inch of leaf area near the center of the fourth leaf from the top on 50 consecutive plants in each of 2 rows, beginning at one end of the plot on one row and at the opposite end on the other row. Five records were made at Florence, 8 at Tallulah, 12 at College Station, and 6 at Waco. The records at each locality for each plot were averaged to obtain the mean number during the period of treatment.

Yield was the total amount of seed cotton picked on the buffer-enclosed one-fiftieth-acre area in each plot.

RESULTS.—Table 1 presents treatment averages of (1) the boll weevil infestation records expressed as percentages of squares punctured, (2) the numbers of cotton aphids per square inch of leaf area, and (3) the pounds of seed cotton per plot for each locality and for all localities, together with the corresponding analyses of variance. The percentages of weevil-punctured squares were transformed to equivalent angles, but the analyses in which these angles were used are not given because the conclusions in regard to treatment drawn from them were identical with those from the analyses in which the percentages of punctured squares were used.

In each of the three sets of analyses for the combined records for all localities the treatment-locality interaction is highly significant, indicating that the differential response to treatments at the various localities may be attributed to the combination of infestations which prevailed during the course of each experiment. At Florence there was an extremely light boll weevil infestation with a cotton aphid infestation that would be considered heavy. At Waco there was a light infestation of the boll weevil and an extremely light infestation of the aphid, whereas at Tallulah and College Station both boll weevil and cotton aphid infestations would be considered heavy. Following the treatments highly significant differences between boll weevil infestations and between yields occurred at Tallulah and College Station but not at Florence and Waco. The differences between aphid infestations following treatments were highly significant at all localities.

To determine the significance of the response of boll weevil and aphid infestations and yield to applications of calcium arsenate, nicotine, and both, the treatment mean square in each experiment has been divided into parts proportionate to each source of variation. At Florence calcium arsenate (A and C *vs.* B and D) did not significantly affect either boll weevil infestation or yield, whereas at Tallulah, College Station, and Waco it gave significant reductions in boll weevil infestation and at Tallulah and College Station significant increases in yield. It also caused significant increases of aphids at all localities. Nicotine dust (A and B *vs.* C and D) did not significantly affect either boll weevil infestation or yield at any locality, but caused significant reductions in aphids at all localities except Florence. Calcium arsenate and nicotine dust (A and D *vs.* B and C) interacted to cause significant reductions in aphids at Tallulah, College Station, and Waco and to give a significant increase in yield at Tallulah.

Calcium arsenate alone (A *vs* B) increased the yield at all localities, although at Florence and Waco the increases were not significant. Nicotine dust alone (A *vs.* C) increased the yield only at Florence, and not significantly. Treatments with calcium arsenate and also with nicotine (A *vs.* D) gave a greater increase in yield than either of the other treatments at Florence, Tallulah, and College Station. The increased yield caused by treatments with both calcium arsenate and nicotine over that with calcium arsenate alone (B *vs.* D) was calculated to be 95 pounds of seed cotton per acre at Florence, 205 pounds at Tallulah, and 80 pounds at College Station as compared with a loss of 20 pounds at Waco. The difference was highly significant at Tallulah and nonsignificant at all other localities. The average increased yield for all localities was 90 pounds per acre. These increased yields are associated with reductions in cotton aphid populations of 2.31 aphids per square inch at Florence, 2.19 at Tallulah, 6.51 at College Station, and 0.47 at Waco.

The reductions in aphid population and increases in yield appear to be inconsistent and require some explanation. At Florence, in the plots treated with calcium arsenate alone on July 1 and 6, cotton aphids increased from 0.04 per square inch on July 1 to 2.12 on July 10. Reductions in aphids from 6.59 on August 5 to 0.58 on August 13 and 0.62 on August 19 followed excessive rains starting on August 10. At Tallulah in the plots dusted with calcium arsenate alone the first application was

made on July 9. Following seven applications, four of which were effective, cotton aphids increased from 0 on July 9 to 2.19 on August 5. The insects apparently increased to injurious numbers long before the late-planted cotton reached maturity. Under these conditions decrease in yield from aphid attack and gain due to aphicides would be expected to be greater at Tallulah than at Florence. At College Station in the plots treated with calcium arsenate alone the aphids did not increase so rapidly as at Florence and Tallulah. Seven applications of calcium arsenate were required before the population increased from 0 on June 21 to 1.84 on July 30. The aphids apparently did not increase to seriously injurious numbers until the cotton had practically ceased to produce squares. Consequently the increased yield would not be expected to be so great at College Station as at Tallulah. At Waco in the plots dusted with calcium arsenate alone, following five applications, the population increased from 0.22 on July 5 to 1.29 on July 30 and then decreased after that date. These slight increases in aphid populations would not be expected to reduce the yields of seed cotton.

SUMMARY.—Experiments employing a factorial design were conducted in 1940 at Florence, S. C., Tallulah, La., College Station, Texas, and Waco, Texas, to study the effect on infestations of the boll weevil, *Anthonomus grandis* Boh., and the cotton aphid, *Aphis gossypii* Glov., and on cotton yield, of applications of calcium arsenate dust, of nicotine dust, and of both, when these were tried in all combinations at two levels (presence and absence).

Applications of calcium arsenate, and of both calcium arsenate and nicotine dust, were followed by significant reductions in boll weevil infestation at Tallulah, College Station, and Waco and significant increases in yield at Tallulah and College Station.

Applications of nicotine dust, and of both nicotine dust and calcium arsenate were followed by significant reductions in cotton aphid infestation at all localities except Florence, but they did not significantly affect boll weevil infestation or yield at any locality.

Applications of both calcium arsenate and nicotine dust interacted to cause significant reductions in cotton aphid infestation at Tallulah, College Station, and Waco and to cause a significant increase in yield at Tallulah.

Applications of calcium arsenate were followed by significant increases in aphid infestation at all localities.

The increased yield following applications of both calcium arsenate and nicotine dust over that following calcium arsenate alone was 95 pounds of seed cotton per acre at Florence, 205 pounds at Tallulah, and 80 pounds at College Station, but at Waco there was a loss of 20 pounds.—3-17-41.

LITERATURE CITED

Gaines, R. C., M. T. Young, and G. L. Smith. 1940. Effect of insecticides used in boll weevil control upon aphids and mirids. JOUR. ECON. ENT. **33**(5): 792–6.

STUDIES OF THE PHYSIOLOGY AND TOXICOLOGY OF BLOWFLIES

A series of seven papers published in three bulletins by the Council for Scientific and Industrial Research, Melbourne, Australia. These papers are issued as follows:

1. Lennox, F. G. 1939. The development of a synthetic medium for aseptic cultivation of larvae of *Lucilia cuprina*. Pamphlet 90, 24 p., 1 plate.
2. Lennox, F. G. 1940. The action of stomach larvicides on *Lucilia cuprina*. Pamphlet 101: 9–49.
3. Lennox, F. G. and L. G. Webber. 1940. The toxicity of some arsenicals to larvae of *Lucilia cuprina*. Pamphlet 101: 51–67.
4. Lennox, F. G. 1940. The action of contact larvicides on *Lucilia cuprina*. Pamphlet 101: 69–131.
5. Waterhouse, D. F. 1940. The hydrogen ion concentration in the alimentary canal. Pamphlet 102: 7–27.
6. Waterhouse, D. F. 1940. The absorption and distribution of iron. Pamphlet 102: 28–50.
7. Lennox, F. G. 1940. A quantitative examination of the iron content of *Lucilia cuprina*. Pamphlet 102: 51–67.

Summaries are given at the beginning of each pamphlet. Pamphlets 101 and 102 were printed by a photo-lithographic process.—F.L.C.

Tests of Insecticides for Boll Weevil Control During 1940[1]

J. C. GAINES, *Texas Agricultural Experiment Station*

In a recent report by the author (Gaines 1940) it was shown that a special calcium arsenate, containing large particles and a high percentage of water-soluble arsenic pentoxide, gave significantly better control of the rapid plant bug, *Adelphocoris rapidus* (Say), than did a commercial calcium arsenate. This special poison also gave a higher degree of control of the boll weevil, *Anthonomus grandis* Boh., and a higher yield than the commercial calcium arsenate, but the differences were not found to be significant. Another special calcium arsenate containing a higher percentage of water-soluble arsenic pentoxide than that used in the previous experiment, a cryolite-sulfur mixture, and commercial calcium arsenate, were tested against the boll weevil at College Station, Texas, and Tallulah, La., and the results are reported herein. During 1940, at both locations, this special poison was compared with commercial calcium arsenate and a synthetic cryolite-sulfur mixture (85-15) for boll weevil control, and the effects on aphids and mirids were observed.

PLATS AND TREATMENTS.—Eighteenth-acre plots (dusting area) were arranged in randomized blocks, and each treatment was replicated four times at each location. After the buffer areas were eliminated, the picking area of each plot was one-fiftieth acre. The treatments consisted of a check; commercial calcium arsenate;[2] special calcium arsenate containing 19.0 per cent water-soluble arsenic pentoxide with a mean surface diameter (by air permeation) of 3.5 microns; and synthetic cryolite-sulfur mixture (85-15) containing 73.2 per cent of sodium fluoaluminate.

The insecticides were applied in the early morning at the rate of from 7.2 to 10 pounds per acre at approximately 5-day intervals. Ten applications were made at each location, but only eight were effective at Tallulah. The tests were begun at College Station on June 21, when an average of 18.5 per cent of the squares on all plats were found to be punctured, and at Tallulah on July 16, when 23.0 per cent of the squares were found punctured.

RECORDS.—The boll weevil infestation records were made at approximately 5-day intervals at College Station and at 7-day intervals at Tallulah. Two hundred squares were examined on the four center rows of each plat on each date, and all punctured squares, both egg and feeding punctures, were recorded. The seven infestation records at College Station and five at Tallulah made during the dusting period were averaged (Table 1).

Aphid-population records were also made at approximately 5-day intervals during the dusting period. The aphids were counted on a square inch of leaf area in the center of the fourth leaf from the top on each of 50 consecutive plants at each end of each plat. The averages of the eight records at College Station and the seven records at Tallulah are shown in table 1. One application of sulfur to which 2.25 per cent of nicotine, in the form of nicotine sulfate, had been added was applied to all plats at College Station for aphid control on August 15, and three applications of tobacco dust containing 3 per cent of nicotine were made at Tallulah on August 12 and 27 and September 4.

The numbers of mirids, *Lygus pratensis oblineatus* (Say) and *Adelphocoris rapidus* (Say), found on the squares examined for boll weevil punctures, were also recorded. The mirid population was not high enough for records to be made at College Station, but the averages (5 records) found at Tallulah are shown on table 1.

Records of bollworms show that this pest was not injurious at either location.

RESULTS.—The analyses of variance of boll weevil infestation, aphid population, mirid population, and yields are shown in table 2. Since in every experiment the *F* test indicated that the treatment means differed significantly among themselves, these means and the differences required to indicate the minimum values that can

[1] Technical Contribution 638, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due J. C. Barton, H. A. Dean, and G. C. Menzies, of the Texas Agricultural Experiment Station for assistance in taking the field notes at College Station. R. C. Gaines, M. T. Young, G. L. Garrison, G. D. Green, G. H. Rainwater, J. E. Gillaspy, and W. A. Lee, all of the Bureau of Entomology and Plant Quarantine, conducted the experiment at Tallulah.

[2] The calcium arsenate used at College Station contained 7.7% and that used at Tallulah 7.3% of water-soluble arsenic pentoxide (determined by the New York method). The chemical determinations were made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

Table 1.—Average weevil infestation, aphid population, mirid population, and yield of seed cotton in experiments for boll weevil control at College Station, Texas, and Tallulah, La.

Location	Block	Checks	Commercial Calcium Arsenate	Special Calcium Arsenate	Synthetic Cryolite-Sulfur (85–15)	Minimum Difference Required for Significance
		Boll weevil infestation, per cent				
	1	50.4	17.6	19.9	35.2	
College	2	37.5	17.6	24.7	40.0	
Station	3	39.6	20.2	17.9	28.8	
	4	36.3	11.6	17.1	23.1	
	Ave.	41.0	16.8	19.9	31.3	7.01
	1	42.4	29.3	20.6	40.0	
	2	50.5	37.6	38.7	47.1	
Tallulah	3	53.9	42.8	44.9	54.3	
	4	61.4	36.7	44.8	50.4	
	Ave.	52.1	36.6	37.2	48.0	6.22
Average both locations		46.5	26.7	28.6	39.9	4.36
		Number of aphids per square inch				
	1	.04	6.74	14.19	.19	
College	2	.18	8.52	4.99	.05	
Station	3	.06	2.05	10.18	.15	
	4	.04	3.59	6.48	.15	
	Ave.	.08	5.22	8.96	.14	4.12
	1	.26	1.10	1.78	.30	
	2	.59	1.22	1.02	.42	
Tallulah	3	.51	.97	1.68	.55	
	4	.48	1.64	1.64	1.04	
	Ave.	.46	1.23	1.53	.58	.43
Average both locations		.27	3.23	5.24	.36	1.93
		Number of mirids per 200 squares				
	1	4.2	1.6	.6	1.8	
	2	6.2	2.6	1.0	7.0	
Tallulah	3	3.8	3.8	1.2	2.8	
	4	3.6	2.8	2.4	2.8	
	Ave.	4.5	2.7	1.3	3.6	2.08
		Average yield, pounds per plot				
	1	13.58	28.23	26.40	20.79	
College	2	20.11	26.25	25.31	18.22	
Station	3	17.95	23.57	20.32	21.75	
	4	15.50	21.10	25.61	23.51	
	Ave.	16.78	24.79	24.41	21.07	4.90
	1	25.6	39.2	42.9	29.4	
	2	26.7	39.8	41.2	29.7	
Tallulah	3	24.1	37.8	32.2	27.8	
	4	23.0	33.9	27.6	24.1	
	Ave.	24.9	37.7	36.0	27.8	4.30
Average, both locations	Per plot	20.82	31.23	30.19	24.41	3.03
	Per acre	1,041	1,562	1,510	1,221	152

be considered as significant were computed and placed in table 1.

It will be noted that commercial calcium arsenate and the special calcium arsenate were equally effective against the weevil at both locations. Both calcium arsenates gave significantly better control than the synthetic cryolite-sulfur mixture. The cryolite mixture gave a significantly better control of weevils than the checks at College Station but not at Tallulah, while the combined analysis shows the cryolite mixture to be significantly better than the checks.

The differences between the aphid population found on the checks and that

Table 2.—Analyses of variance using data as indicated on experiments for boll weevil control at College Station, Texas, and Tallulah, La.

Locality and Source of Variation	DF	Mean Square Pertaining to—			
		Boll Weevil Infestation	Population of Aphids	Mirids	Yield
College Station					
Blocks	3	63.16	5.59		2.13
Treatments	3	496.53†	74.36†		55.23*
Error	9	19.27	6.66		9.40
Total	15	123.50	19.98		17.11
Tallulah					
Blocks	3	215.91	.12	3.15	47.71
Treatments	3	239.43†	1.06†	7.26*	155.24†
Error	9	15.16	.07	1.68	7.27
Total	15	100.17	.28	3.09	44.95
Combined experiments					
Blocks	6	139.54	2.86		24.92
Treatments	3	708.88†	46.49†		193.54†
Locations	1	2078.51	56.18		768.32
Treatment x Location	3	27.09	28.93†		16.92
Error	18	17.22	3.36		8.33
Total	31	175.27	11.62		548.14

* Significant. † Highly significant.

found on the plats treated with the cryolite mixture were nonsignificant. The separate analysis shows the difference in the aphid population on the plats treated with the calcium arsenates to be nonsignificant while in the combined analysis of the data the number of aphids found on the plats treated with special calcium arsenate was significantly greater.

The special calcium arsenate gave significantly better control of mirids than the cryolite-sulfur mixture. This population was causing little if any injury.

At Tallulah the calcium arsenates were equally effective and significantly better than the cryolite-sulfur mixture. In the combined analysis the two calcium arsenates were equally effective, both gave a significant increase in yield over the cryolite-sulfur mixture, and all insecticides gave a significant increase over the checks.

SUMMARY.—A special calcium arsenate containing large particles and a high percentage of water-soluble arsenic pentoxide, a commercial calcium arsenate, and a cryolite-sulfur mixture were tested against the boll weevil at College Station, Texas, and Tallulah, La. Records were also kept on the aphid populations at both locations and on the mirid population at Tallulah. The two calcium arsenates were equally effective in reducing the weevil population, and there was a nonsignificant difference in yield. The calcium arsenates gave a significant control of weevils and significant increases in yield over the cryolite-sulfur mixtures. All insecticides gave significant control and significant increases in yield over the checks. The special calcium arsenate contributed to higher increases in the aphid population, but apparently not enough to affect the yield. At Tallulah the mirid control was significantly better on the plats treated with the special calcium arsenate than on the plats treated with cryolite-sulfur mixture, but the population was low, causing little injury. The special calcium arsenate gave better control of mirids than the commercial form, but the difference was not significant.—2-17-41.

LITERATURE CITED

Gaines, J. C. 1940. Tests of insecticides for certain cotton insects during 1939. JOUR. ECON. ENT. 33(4): 684–8.

Insecticide Tests on the Bollworm, Boll Weevil, and Cotton Leaf Worm in 1940

R. W. Moreland, E. E. Ivy, and K. P. Ewing,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

During 1940 several series of cage toxicity tests were conducted at Waco, Texas, in which the efficacy of calcium arsenate and other insecticides or mixtures of insecticides were compared against the bollworm, *Heliothis armigera* (Hbn.), boll weevil, *Anthonomus grandis* Boh., and cotton leaf worm, *Alabama argillacea* (Hbn.). The tests were limited by the small number of cages available. Between 178 and 309 insects of each species were utilized with each of three insecticides, while between 8 and 38 insects were used with each of the other insecticides. Although in tests where only a few insects were utilized the results should be considered preliminary, certain trends were noticeable which appeared consistently in tests where large numbers of insects were used. A full report of all tests is given.

Insecticides.—The calcium arsenate used contained on an average 5.4 per cent of water-soluble arsenic pentoxide by the New York method and 41.4 per cent of total arsenic pentoxide, and had a mean surface particle diameter of 1.0 micron (by air permeation). The barium fluosilicate was 98.3 per cent pure, with a mean surface particle diameter of 3.4 microns. The sodium fluosilicate was 99.5 per cent pure, with a mean surface particle diameter of 25 microns in the regular material and of 1.8 microns in the micronized material. The basic copper arsenate contained a total of 38.6 per cent of arsenic pentoxide and 54.7 per cent of copper, conforming fairly closely to the formula $Cu(CuOH)AsO_4$; the content of water-soluble arsenic pentoxide was 0.03 per cent, and the mean surface particle diameter was 1.2 microns, 100 per cent passing a 325-mesh screen. The cryolite materials contained 50.2 per cent, 66.1 per cent, 87.9 per cent, and 94.6 per cent of sodium fluoaluminate. The lead arsenate and Paris green were standard commercial products. The sulfur used in the mixture with basic copper arsenate was 97.4 per cent pure and was micronized; it had a mean surface particle diameter of 6.2 microns and 100 per cent passed a 325-mesh screen. The lime used in the mixture was ordinary hydrated lime purchased locally.

Method.—The method of conducting the tests was a modification of that used for the cotton flea hopper (Ewing 1931). Cotton growing on the laboratory grounds was used for all tests. The insecticides were applied as dusts early in the morning to selected plants, and a cage 18 by 18 by 24 inches was placed over each plant. Rotary hand guns were used for the dusting, a different gun being used for each insecticide. The guns were calibrated to distribute dust at a certain rate and thus the quantities per acre were approximated.

Ten field-collected boll weevils and ten field-collected third- or fourth-instar cotton leaf worm larvae were used per cage. The leaf worms and boll weevils were placed on their respective plants immediately after the cages were put in position. In tests with the bollworm, laboratory-reared larvae in the second, third, and fourth instars were used. These were placed under the bracts of squares or in the tips of the cotton plants a few minutes before the plants were dusted. In the first tests only one bollworm larva was used per cage, but in all later tests five larvae were used per cage, since it was found that this number could be used without displaying cannibalistic tendencies. The cages were inspected for dead insects at intervals of 12 hours, more or less, for a period of 5 days.

Results with the Bollworm.—Calcium arsenate dust is the standard recommendation for bollworm control on cotton, but its effectiveness is limited because of its slow action and the low mortality it causes among large-size larvae. As shown in table 1, basic copper arsenate, lead arsenate, and cryolite each killed more bollworms in a shorter time than did calcium arsenate. After 120 hours the kill from calcium arsenate was only 62.3 per cent, as compared with kills of 91.8, 87.9, 83.7 and 82.8 for basic copper arsenate and lime mixture, lead arsenate, basic copper ar-

[1] Chemical analyses of the insecticides were made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine.

Table 1.—Relative toxicity of various insecticides against the bollworm as determined by cage tests.

Insecticide	Pounds per Acre	Number of Worms	Mortality of Worms at Various Intervals After Poison Application, Per Cent: Hours 12	24	36	48	60	72	84	96	108	120
Basic copper arsenate and lime 1:1	15–20	208	6.3	19.2	33.7	45.2	59.1	71.6	80.3	87.5	90.9	91.8
Lead arsenate	8–10	33	15.2	36.4	54.5	60.6	78.8	87.9	87.9	87.9	87.9	87.9
Basic copper arsenate and sulfur 1:1	15–20	25	0	4.0	16.0	28.0	40.0	52.0	68.0	68.0	80.0	84.0
Basic copper arsenate	8–10	251	9.6	21.1	35.1	51.0	61.4	69.3	74.5	79.3	82.1	83.7
Cryolite: 66.1% Na_3AlF_6	15–20	29	20.7	44.8	51.7	65.5	69.0	72.4	75.9	75.9	75.9	82.8
87.9% Na_3AlF_6	15–20	38	7.9	26.3	39.5	52.6	60.5	60.5	65.8	68.4	78.9	78.9
50.2% Na_3AlF_6	15–20	11	18.2	27.3	27.3	27.3	54.5	54.5	54.5	72.7	72.7	72.7
94.6% Na_3AlF_6	15–20	21	9.5	19.0	33.3	38.1	57.1	66.7	66.7	66.7	66.7	66.7
Calcium arsenate	8–10	244	1.6	7.8	20.5	28.7	35.7	41.8	48.8	56.1	59.8	62.3
Calcium arsenate 92.5% and Paris green 7.5%	8–10	17	0	5.9	23.5	23.5	41.2	41.2	47.1	47.1	52.9	58.8
Barium fluosilicate	8–10	17	11.8	11.8	17.6	29.4	47.1	47.1	52.9	58.8	58.8	58.8
Sodium fluosilicate, micronized	8–10	8	0	25.0	25.0	25.0	25.0	37.5	37.5	37.5	37.5	50.0
Sodium fluosilicate, regular	8–10	8	0	0	12.5	12.5	12.5	37.5	37.5	37.5	37.5	37.5
Check		161	0	0	.6	.6	.6	.6	1.2	2.5	2.5	3.1

senate alone, and cryolite containing 66.1 per cent of sodium fluoaluminate.

Undiluted basic copper arsenate did not produce a dust cloud comparable with that produced by calcium arsenate, nor did it cover the plant so thoroughly. When it was mixed with equal parts of hydrated lime or sulfur and the delivery rate doubled, a much better distribution and coverage was obtained and the toxicity to the insect was increased. The sulfur mixture seemed to adhere to dry cotton plants better than the lime mixture.

Since basic copper arsenate appeared to be killing a greater proportion of the large bollworms then any of the other materials, it was decided to weigh each bollworm immediately before dusting began. Relative mortalities due to basic copper arsenate, basic copper arsenate and lime mixture, and calcium arsenate to worms of four weight groups are shown in figure 1.

With all insecticides the mortalities varied inversely with the size of bollworm, with one exception. The mortality from basic copper arsenate was 10 per cent higher for larvae weighing over 45 milligrams than for larvae weighing 31 to 45 milligrams. In all weight groups the basic copper arsenate and lime mixture was the most effective. Of these three materials calcium arsenate was the least effective in all groups, the difference being most pronounced with large worms. In the group of large worms the mortality from basic copper arsenate was 77.3 per cent as compared with 45.8 per cent from calcium arsenate. The mixture of basic copper arsenate and lime killed approximately the same percentage of the large worms (77.78) as calcium arsenate killed of the small worms (77.36).

Table 2.—Relative toxicity of several insecticides against the boll weevil as determined by cage tests.

Insecticide	Pounds per Acre	Number of Weevils	Mortality at Various Intervals After Poison Application, Per Cent: Hours 12	24	36	48	60	72	84	96	108	120
Basic copper arsenate and sulfur 1:1	15–20	20	0	0	0	25.0	35.0	55.0	60.0	70.0	80.0	80.0
Basic copper arsenate and lime 1:1	15–20	309	1.6	8.7	15.5	22.6	29.8	38.2	48.2	56.0	65.7	77.3
Basic copper arsenate	8–10	307	.7	4.2	11.1	16.9	25.4	32.9	42.3	51.1	60.3	69.7
Calcium arsenate	8–10	306	1.3	3.3	7.2	11.4	16.7	22.2	28.1	36.3	42.0	48.0
Check		175	0	0	0	0	.6	.6	1.1	1.1	1.1	1.7

No plant injury was observed following the use of any of the materials tested except the sodium fluosilicates.

RESULTS WITH THE BOLL WEEVIL.—Most of the tests with boll weevils were conducted toward the latter part of the season and under conditions rather unfavorable for maximum kill; namely, light to medium winds and no dews when the dust applications were made and comparatively low mean temperatures. Since calcium arsenate, basic copper arsenate, and the basic copper arsenate and lime mixture were tested simultaneously under identical weather and other conditions, the results shown in table 2 may be considered representative of their relative efficacy against the boll weevil. It may be noted that the mixture of basic copper arsenate and lime gave a slightly higher kill than the undiluted basic copper arsenate and that each of these materials gave a much higher kill than calcium arsenate. Although the results of the limited number of tests with the mixture of basic copper arsenate and sulfur could hardly be

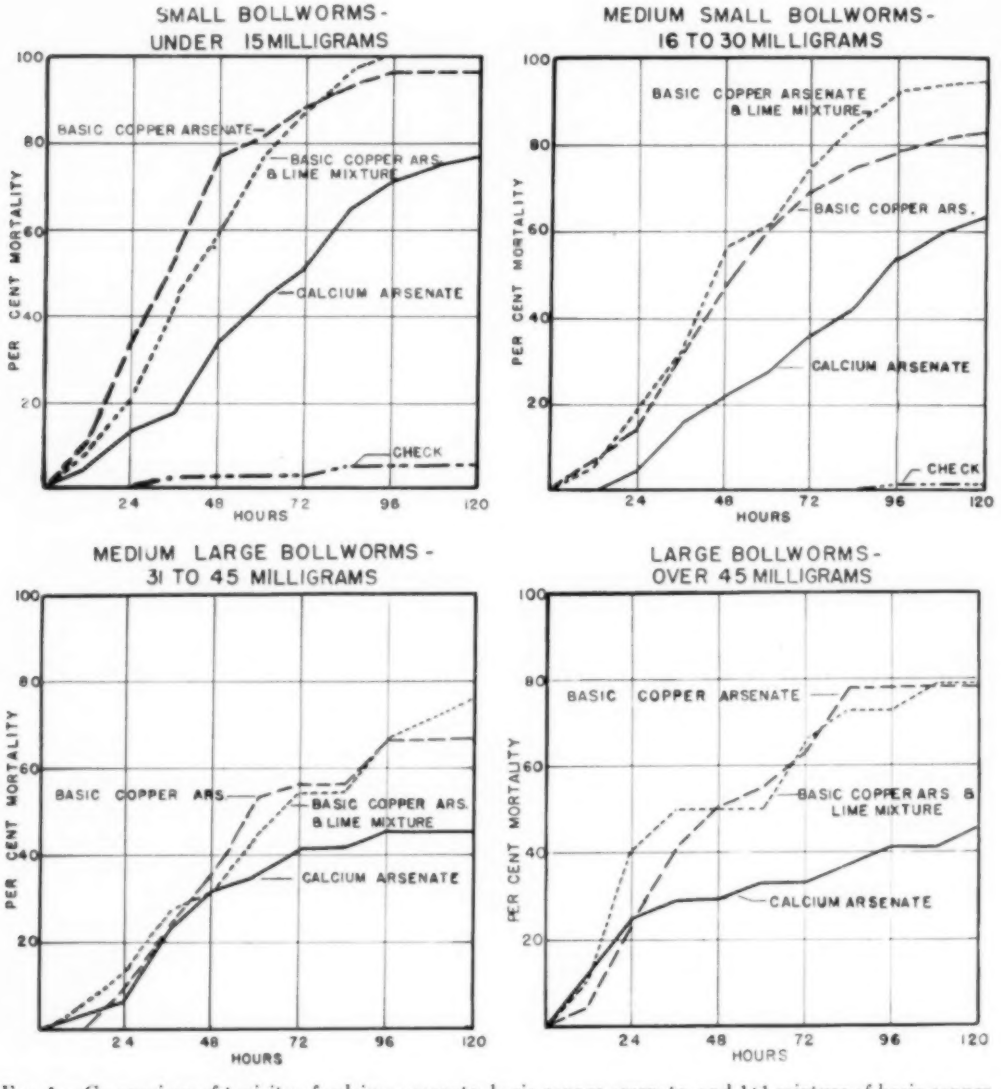

SMALL BOLLWORMS - UNDER 15 MILLIGRAMS
MEDIUM SMALL BOLLWORMS - 16 TO 30 MILLIGRAMS
MEDIUM LARGE BOLLWORMS - 31 TO 45 MILLIGRAMS
LARGE BOLLWORMS - OVER 45 MILLIGRAMS
PER CENT MORTALITY
HOURS
BASIC COPPER ARSENATE
BASIC COPPER ARS. & LIME MIXTURE
BASIC COPPER ARS.
CALCIUM ARSENATE
CHECK

FIG. 1.—Comparison of toxicity of calcium arsenate, basic copper arsenate, and 1:1 mixture of basic copper arsenate and lime on different sizes of bollworms in cage experiments at Waco, Texas during 1940.

interpreted as conclusive, they indicate the possibility of sulfur being utilized as a satisfactory diluent. These tests also show a quicker kill of boll weevils from the basic copper arsenate than from calcium arsenate.

RESULTS WITH THE COTTON LEAF WORM.—The insecticides tested against the leaf worm and the results secured are given in table 3. Basic copper arsenate and mixtures of this material with lime and sulfur gave a quicker and higher kill of leaf worms than did calcium arsenate.

Table 3.—Relative toxicity of several insecticides against the cotton leaf worm as determined by cage tests.

Insecticide	Pounds per Acre	Number of Worms	Mortality of Worms at Various Intervals after Poison Application, Per Cent: Hours 12	24	36	48	60	72	84	96	108	120
Basic copper arsenate and sulfur 1:1	15–20	30	0	24.2	46.7	60.0	73.3	86.7	86.7	93.3	96.7	96.7
Basic copper arsenate and lime 1:1	15–20	178	4.5	18.0	37.1	50.0	61.8	75.3	83.7	88.8	91.6	93.3
Basic copper arsenate	8–10	180	3.3	13.3	30.6	46.1	56.1	69.4	74.4	81.7	85.6	87.2
Calcium arsenate	8–10	180	.6	11.1	26.7	47.8	54.4	63.9	66.7	70.0	72.2	72.8
Check		120	0	0	1.7	2.5	2.5	5.0	6.7	7.5	7.5	8.3

SUMMARY.—In cage tests at Waco, Texas, in 1940 various insecticides and mixtures of insecticides as dusts were compared with calcium arsenate against the bollworm, *Heliothis armigera* (Hbn.), boll weevil, *Anthonomus grandis* Boh., and cotton leaf worm, *Alabama argillacea* (Hbn.). When bollworm larvae were arranged into four weight groups it was found that in general mortalities due to insecticides varied inversely with the weight of the larvae. A mixture of basic copper arsenate and lime killed a slightly higher percentage of large worms (over 45 milligrams) than calcium arsenate killed of small worms (under 15 milligrams). Against bollworm larvae of all weight groups the average mortality after 120 hours was 91.8 per cent from the basic copper arsenate and lime mixture, 87.9 per cent from lead arsenate, 83.7 per cent from undiluted basic copper arsenate, 82.7 per cent from cryolite containing 66.1 per cent of sodium fluoaluminate, and 62.3 per cent from calcium arsenate.

Basic copper arsenate and mixtures of this material with lime and with sulfur gave somewhat higher kills of the boll weevil and of the leaf worm than did calcium arsenate.—2-26-41.

LITERATURE CITED

Ewing, K. P. 1931. Cage tests of the effectiveness of insecticidal dusts for the control of the cotton flea hopper. JOUR. ECON. ENT. **24**(4): 821–7.

TAR OIL SPRAYS

Gimingham, C. T., *et al.* 1941. Specifications and methods of analysis for tar oil winter washes. Bul. 122 Ministry of Agriculture and Fisheries, pp. I–IV and 1–22. Obtainable from H. M. Stationery Office, York House, Kingsway, London, W.C. 2.

Coal tar oil emulsions for dormant sprays have been studied and used more in England than in the United States. Consequently one might expect England to take the lead in setting up specifications and corresponding methods for analysis for such dormant oils. The present bulletin was prepared by a committee of seven, headed by C. T. Gimingham. Three members of the committee were official insecticide chemists and entomologists and four represented the manufacturers of coal tar oils. The resulting bulletin gives no insecticidal or phytocidal reasons for the particular chemical specifications adopted for miscible tar oils and tar oil stock emulsions. The corresponding methods of analysis are given in the form of precise directions, exactly as is done by our Association of Official Agricultural Chemists.—F.L.C.

A Factorial Experiment Comparing Insecticides for Control of Cotton Insects[1]

J. C. GAINES, *Texas Agricultural Experiment Station, College Station*

It is a common practice in Texas to apply control measures (contact) for flea hopper, *Psallus seriatus* (Reut.), early in the season and later to adequately control bollworms, *Heliothis armigera* (Hbn.), and weevils, *Anthonomus grandis* Boh., with stomach poisons. The main objective of the experiment on which this paper is based and which was conducted in the Brazos River Bottoms near College Station during the season of 1940 was to obtain information on the value of insecticides used in a schedule of applications for the control of all cotton insects. The factorial experiment herein discussed affords valid comparisons between several treatments; *i.e.*, no treatment, sulfur alone, three stomach poisons, and combination of sulfur with later applications of the stomach poisons. In this type of experiment, all plats are used in making estimates of the effects of the different insecticides used, giving much greater precision than could be obtained from separate experiments. Previous reports (Gaines 1937, 1939, 1940, 1941; Moreland 1938; Moreland & Bibby 1931; and Moreland & Gaines 1939) have shown that calcium arsenate was the most effective and economical control for bollworms. Gaines (1941) shows that arsenate of lead-clay, 90–10, and natural cryolite-sulfur, 85–15, were more effective than commercial calcium arsenate previously recommended for bollworm control using bollworm injury as the criterion.

Heretofore, no evaluation has been made of flea hopper control alone, bollworm or weevil control alone when all three insects cause injury in the same experiment.

PLAT ARRANGEMENT AND TREATMENTS.—This experiment consisted of 36 plats each nine rows wide and of sufficient length to make one-nineteenth acre (dusting area). The picking area after the buffers were eliminated was one-fortieth acre. The plats were arranged in three blocks, each containing 12 plats arranged at random. In each block 6 plats were treated with sulfur for hopper control, 3 of which were later treated with stomach poisons (one plat received each of the following: calcium arsenate, lead arsenate-clay, 90–10, and natural cryolite-sulfur, 85–15). Of the remaining 6 plats, 3 were untreated and 3 were treated each with one of the stomach poisons. The calcium arsenate contained 4.5 per cent water-soluble arsenic pentoxide[2] (New York Method) and 41.7 per cent total arsenic pentoxide with a mean surface diameter (by air permeation) of 1.2 microns. The lead arsenate-clay (90–10) mixture contained 0.12 per cent water-soluble arsenic pentoxide (by A. O. A. C. Method) and 29.2 per cent total arsenic pentoxide; and the natural cryolite-sulfur-mixture contained 76.5 per cent sodium fluoaluminate.

Table 1.—Analysis of variance with respect to flea hopper infestation on factorial experiment for cotton insect control at College Station, Tex.

SOURCE OF VARIATION	DF	SUM OF SQUARES		MEAN SQUARE
Blocks	2	18.53		9.26
Treatments	1	180.00		180.00†
Interaction, block-treatment	2	5.19	error	10.51
Within blocks plats treated alike	30	331.37		
Total	35	535.09		

† Highly significant.

Two applications of sulfur at the average rate of 14.6 pounds per acre were made on June 26 and July 9 and six applications of the stomach poisons at the average rate of 9.4 pounds per acre were made from July 24 to August 22 at approximately 5-day intervals. All applications were made in the early morning (5 to 6 A.M.) while the cotton was wet with dew.

RECORDS.—Flea hopper records were made by recording the number of nymphs and adults on 100 terminals of consecutive plants in the middle of each plat. These records were begun early in June, but not

[1] Technical contribution #642, Texas Agricultural Experiment Station in cooperation with the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture. Thanks are due J. C. Barton, H. A. Dean, and G. C. Menzies for assistance in taking the field notes.

[2] Chemical and physical determinations were made by the Division of Insecticide Investigations, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture.

until June 26 did the population increase to sufficient numbers for control measures to be applied. Three records were made at weekly intervals during the dusting period in which two applications of sulfur were made.

The bollworm injury records were made by examining 100 squares and 100 bolls on consecutive plants in each plat and recording the number of injured forms (squares and bolls). Six records at approximately 5-day intervals were made from July 29 to August 22, inclusive.

The boll weevil infestation records were made at approximately 5-day intervals during the dusting period. One hundred squares were examined on each plat on each date and all punctured squares, both egg and feeding, were recorded. Six such records were made from July 29 to August 22.

The number of rapid plant bugs, *Adelphocoris rapidus* (Say), found on the squares examined for boll weevil punctures were recorded. Two records were made, one on August 17 and the other August 22.

Two cotton aphid, *Aphis gossypii* Glov., population records were made late in the season, one on August 19 and the other September 4. The numbers of aphids were recorded on 1 square inch of leaf area in the center of the fourth leaf from the top on 100 consecutive plants in the middle of each plat.

The cotton was picked on each plat, one-fortieth acre, and the average yield is shown in table 2.

RESULTS.—Analyses of variance using the individual plat averages of flea hopper infestation, bollworm injury, boll weevil infestation, rapid plant bug population, aphid population, and yield of seed cotton are shown in tables 1 and 2. The averages for these different criteria were computed using the number of plats as indicated in table 3. It will be noted that all combinations of the several insecticide treatments were used. Thus, information was obtained on the responses to the different insecticides (contact and stomach poisons), and also on the effect of applications of sulfur with later applications of each of three stomach poisons. The yield is the most important criterion for measuring the results of this experiment. It was possible for early applications of sulfur to affect the hopper infestation and the fruit production, but it could not affect the population of the other insects which occurred later after the sulfur applications had been made. Hence, as far as flea hopper population is concerned, the experiment was a simple one, with 3 blocks each containing 6 plats treated and 6 untreated. The stomach poisons affected all insects except flea hoppers which occurred before the poisons were applied. Comparisons of the effect of stomach poisons on bollworm, boll weevil, rapid plant bug, and aphids

Table 2.—Analysis of variance with respect to bollworm injury, boll weevil infestation, rapid plant bug population, aphid population and yield on factorial experiment for cotton insect control at College Station, Tex.

SOURCE OF VARIATION	DF	MEAN SQUARE PERTAINING TO—				
		Boll-worm Injury, per cent	Boll Weevil Infestation, per cent	Rapid Plant Bug Population, Number	Aphid Popula-tion, Number	Yield per Plat, Pounds
Blocks	2	48.10	69.46	31.86	.14	10.86
Level of Contact Insecticide	1	.27	8.12	15.34	.19*	.08
Level of Stomach Poisons	1	467.28†	444.51†	70.84*	4.37†	614.63†
Source of Stomach Poisons	2	115.30†	68.34*	92.26†	3.65†	3.14
Contact × Stomach Poisons	1	.08	.06	5.84	.02	.01
Contact × Source of Stomach Poisons	2	4.92	1.20	5.29	.08	26.95
Error	26	13.75	17.20	14.52	.03	10.84
Total	35	33.19	33.65	20.81	.37	27.96

* Significant. † Highly significant.

are valid and important. All plats were used in the main comparisons (contact, insecticide, stomach poisons, and their interactions), and 18 plats were used in making the comparisons of the three stomach poisons.

Applications of sulfur for flea hopper control were effective in reducing the hopper population, but this difference in hopper population did not affect the yields. Apparently the hopper infestation was not injurious enough to cause reductions in yield. Applications of stomach poisons significantly decreased the percentage bollworm injury, boll weevil infestation, rapid plant bug population, and significantly increased the aphid population and the yield. Natural cryolite-sulfur, 85-15, and lead arsenate gave better control of bollworms than did calcium arsenate. The natural cryolite mixture gave poor control of weevils as compared to the arsenicals. Calcium arsenate was more effective against rapid plant bugs than arsenate of lead or the natural cryolite mixture, indication that the water-soluble arsenic pentoxide is important in the control of this bug. The aphid population was higher on the plats treated with calcium arsenate than on the plats treated with lead arsenate or natural cryolite mixture, indicating that the water-soluble arsenic pentoxide increases the aphid population. Using yields as the criterion, all stomach poisons were equally effective.

Table 3.—The average flea hopper infestation, bollworm injury, boll weevil infestation, rapid plant bug population, aphid population and yield of seed cotton on factorial experiment at College Station, Tex.

Treatments	Average Flea Hopper Infestation, Number	Average Bollworm Injury, Per Cent	Average Weevil Infestation, Per Cent	Average Rapid Plant Bug Population, Number	Average Aphid Population, Number	Average Yield per Plat, Pounds	Average Yield per Acre, Pounds
No sulfur (18 plats)	18.8	8.5	9.8	11.6	.58	26.20	1048
Sulfur (18 plats)	14.6	8.6	10.8	12.9	.44	26.11	1044
No stomach poison (18 plats)	16.8	10.4	13.8	13.6	.16	22.02	881
Stomach poison (18 plats)	16.8	6.8	6.8	10.8	.90	30.29	1212
No treatment (9 plats)	18.4	10.4	13.3	12.6	.21	22.06	882
Sulfur alone (9 plats)	15.3	10.4	14.3	14.7	.11	21.99	880
Stomach poison alone (9 plats)	19.7	6.7	6.3	10.6	.95	30.35	1214
Sulfur plus later applications of stomach poisons (9 plats)	13.8	7.4	7.2	11.1	.76	30.23	1209
Calcium arsenate (6 plats)	17.5	9.2	4.6	6.8	1.74	30.77	1231
Calcium arsenate alone (3 plats)	20.2	9.6	4.7	7.2	1.95	33.22	1329
Sulfur plus later applications of calcium arsenate (3 plats)	14.9	8.9	4.6	6.5	1.52	28.32	1133
Natural cryolite-sulfur (6 plats)	15.6	5.0	10.7	14.6	.24	29.46	1178
Natural cryolite-sulfur alone (3 plats)	18.9	5.0	9.8	13.3	.21	28.78	1151
Sulfur plus later applications of natural cryolite-sulfur (3 plats)	12.3	5.0	11.5	16.0	.26	30.13	1205
Arsenate of lead-clay (6 plats)	17.2	6.1	5.1	11.0	.61	30.64	1226
Arsenate of lead-clay alone (3 plats)	20.1	5.5	4.5	11.3	.71	29.05	1162
Sulfur plus later applications of arsenate of lead-clay (3 plats)	14.3	6.7	5.6	10.8	.51	32.23	1289

Summary.—A 36-plat factorial experiment was conducted in the Brazos River Bottoms near College Station, Texas, to obtain information on the value of insecticides used in a schedule of applications for control of all cotton insects. Comparisons between the several treatments: no treatment, sulfur alone, three stomach poisons, and the combination of sulfur and later applications of the stomach poisons were made. Sulfur applied early in the season reduced the flea hopper infestation, but did not affect the yield. Applications of all stomach poisons significantly decreased the bollworm injury, boll weevil infestation, rapid plant bug population, and significantly increased the aphid population and yield. Natural cryolite-sulfur, 85-15, and lead arsenate-clay, 90-10, were more effective against bollworms than calcium arsenate, but less effective against the rapid plant bugs and were followed by fewer aphids. The arsenicals were more effective against weevils than the cryolite mixture. Using yields as the criterion, all stomach poisons were equally effective.—2-17-41.

LITERATURE CITED

Gaines, J. C. 1937. Tests of insecticides for cotton boll weevil and bollworm control using the Latin square plat arrangement and analysis of variance. JOUR. ECON. ENT. 30(5): 785–90.

Gaines, J. C. 1939. Insecticide tests for bollworm control during 1938. JOUR. ECON. ENT. 32(6): 821–4.

Gaines, J. C. 1940. Tests of insecticides for certain cotton insects during 1939. JOUR. ECON. ENT. 33(4): 684–8.

Gaines, J. C. 1941. Insecticide tests for bollworm control during 1940. JOUR. ECON. ENT. 34(–): 000–00.

Moreland, R. W. 1938. Recent field tests of insecticides for control of the cotton bollworm. JOUR. ECON. ENT. 31(6): 666–8.

Moreland, R. W., and F. F. Bibby. 1931. Field tests in Texas of insecticides for control of the cotton bollworm (*Heliothis obsoleta* Fabr.) JOUR. ECON. ENT. 24(6): 1173–81.

Moreland, R. W., and J. C. Gaines. 1939. Insecticide tests for the control of the cotton bollworm in 1936. JOUR. ECON. ENT. 32(1): 104–6.

Insecticide Tests for Bollworm Control During 1940[1]

J. C. GAINES, *Texas Agricultural Experiment Station*

Information on the effectiveness of different insecticides for bollworm control is important to the planters of Texas. Results of previous tests on bollworm control have been published at intervals on the cooperative project between the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture and the Texas Agricultural Experiment Station (Gaines 1937, 1939, 1940; Moreland 1938; Moreland & Bibby 1931; and Moreland & Gaines 1939). These tests have shown that, of the materials used, commercial calcium arsenate gave the most effective and economical control of both the weevil, *Anthonomis grandis* Boh., and the bollworm, *Heliothis armigera* (Hbn.). Effort has been made to find a more effective insecticide or one that is as effective as calcium arsenate without causing aphids to increase, and one that is not dangerous to livestock.

Additional tests were made at College Station, Texas during 1940 for determining the comparative effectiveness of synthetic and natural cryolites, lead arsenate, commercial calcium arsenate, and a special calcium arsenate containing a high percentage of water-soluble arsenic pentoxide against the bollworm. Records were obtained showing the action of the various insecticides on the other insects which occurred on the plats during the season.

[1] Technical contribution 640, Texas Agricultural Experiment Station. Thanks are due J. C. Barton, H. A. Dean and G. C. Menzies for assistance in taking the field notes. The analyses of the insecticides were made by the Division of Insecticide Investigations, U. S. Department of Agriculture. The special sample of calcium arsenate was supplied through the courtesy of the Niagara Sprayer and Chemical Company.

ARRANGEMENT OF PLATS.—Two randomized-block experiments located in the same cut were used in these tests. In each experiment there were 5 blocks. A block was divided into 4 plats, equal to the number of treatments. By this arrangement, a treatment assigned to a plat at random was replicated 5 times, once in each block. Each plat was 11 rows wide and of sufficient length to make one-eighteenth acre (dusted area).

POISON APPLICATIONS.—All dust applications were made early in the morning (5 to 7 A.M.) with rotary hand dust guns while the cotton was wet with dew. Eight effective applications of the insecticides were made at the average rate of 9.5 pounds per acre to the dusted plats in both experiments at approximately 5-day intervals from July 22 to August 27, inclusive. In experiment 1 the commercial calcium arsenate contained 7.7 per cent water-soluble arsenic pentoxide (New York method) and 41.7 per cent total arsenic pentoxide, while the special calcium arsenate contained 19.0 per cent water-soluble pentoxide, 42.0 per cent total with a mean surface particle diameter (by air permeation) of 3.5 microns. The synthetic cryolite-sulfur (85-15) contained 73.2 per cent sodium fluoaluminate. In experiment 2 the commercial calcium arsenate contained 4.5 per cent water-soluble arsenic pentoxide, 41.7 per cent total with a mean surface diameter of 1.2 microns. The natural cryolite-sulfur mixture (85-15) contained 76.5 per cent sodium fluoaluminate and the lead-arsenate-

Table 1.—Analysis of variance in respect to bollworm injury, boll weevil infestation, aphid population, rapid plant bug population, and yield on experiments for bollworm control at College Station, Tex.

Source of Variation	DF	Mean Square Pertaining to—				
		Bollworm Injury, Per cent	Weevil Infestation, Per cent	Aphids per Sq. Inch	Rapid Plant Bugs per 100 Sqs.	Yield per Plat, Pounds
Experiment 1						
Blocks	4	6.18	14.20	12.35	7.08	5.59
Treatment	3	36.82[1]	66.71[1]	244.72[1]	61.15[1]	102.50[1]
Error	12	3.99	5.32	8.75	3.95	7.80
Total	19	9.64	16.88	47.64	13.64	22.29
Experiment 2						
Blocks	4	10.21	54.60	20.05	30.69	9.32
Treatment	3	69.04[1]	224.38[1]	77.92[1]	93.35[1]	108.32[1]
Error	12	2.61	27.26	8.32	9.39	4.52
Total	19	14.70	64.14	21.78	27.13	21.92

[1] Highly significant.

clay mixture contained 0.12 per cent water-soluble arsenic pentoxide (by A.O.A.C. method), 29.2 per cent total arsenic pentoxide.

RECORDS.—Records of bollworm injury were made by examining 100 squares and 100 bolls on consecutive plants in each plat and recording the percentage of injured forms (squares and bolls). Six records at approximately 5-day intervals were made on both experiments from July 26 to August 20, inclusive. The averages of the six records on the five replicates are shown in table 2.

Bollworm egg records indicated that no distinct peak occurred in the population but a gradual build up of the infestation caused considerable injury. Eggs were oviposited lower on the plant than usual, thus making it hard to determine the proper time for applications to be made.

Records of boll weevil infestation were made by examining 100 squares in each plat and recording the percentage punctured (both egg and feeding). During the dusting period six records were made on each experiment from July 26 to August 20, inclusive. The averages are shown in table 2.

The number of aphids was recorded on 1 square inch of leaf area on the fourth leaf from the top of 50 consecutive plants

Table 2.—The average percentage bollworm injury, boll weevil infestation, number aphids per square inch, number rapid plant bugs, and yield of seed cotton on experiment for bollworm control at College Station, Tex.

Treatments	Bollworm Injury, Per Cent[2]	Boll Weevil Infestation, Per Cent[2]	Aphids per Sq. Inch, Number[2]	Rapid Plant Bugs per 100 Squares, Number[2]	Yield per Plat, Pounds[2]	Yield per Acre, Pounds[2]
Experiment 1:						
Checks	14.6	10.2	.84	10.0	20.68	931
Commercial calcium arsenate	11.0	3.1	9.11	5.1	29.20	1314
Special calcium arsenate	8.6	2.4	15.68	2.9	30.86	1389
Synthetic cryolite-sulfur (85–15)	9.1	7.2	1.58	9.7	28.48	1282
Minimum difference[1] required for significance	2.7	3.2	4.07	2.7	3.83	173
Experiment 2:						
Checks	14.3	16.2	1.21	11.1	21.16	952
Commercial calcium arsenate	10.1	3.9	9.65	4.7	29.34	1320
Natural cryolite-sulfur (85–15)	6.7	12.1	1.40	14.1	28.91	1301
Lead arsenate-clay (90–10)	6.3	4.9	3.46	13.6	31.96	1438
Minimum difference[1] required for significance	2.2	7.2	3.97	4.2	2.92	132

[1] 5 per cent level.
[2] Average of five replicates.

near each end of each plat, making a total of 100 leaves or square inches per plat for each record. The averages of the four records, from August 15 to September 4, are given.

The number of rapid plant bugs were recorded on 100 squares in each plat on August 15 and 20. The averages are shown in tabular form.

The amount of seed cotton picked from one-forty-fifth acre of each plat was recorded; and the average of five replicates of each treatment is shown in table 2.

RESULTS.—The analysis of variance of percentage of bollworm injury, percentage of boll weevil infestation, aphid population, rapid plant bug population, and yield is shown in table 1. In every case the large mean squares are associated with treatment means, and when the significance attached to such variations was obtained from the *F* test, it was indicated that the differences between some treatment means were highly significant. The averages and the minimum difference required for significance between treatments for each criterion are shown in Table 2.

Experiment 1.—As indicated by the percentage of injured forms, commercial calcium arsenate, special calcium arsenate, and the synthetic cryolite-sulfur mixture were equally effective against bollworms. The two arsenicals gave better control of the weevil and rapid plant bug than the synthetic cryolite. The special calcium arsenate caused larger increases in the aphid population than did the commercial form, but these increases were not of sufficient import to reflect a significant difference in the corresponding yields. Apparently the high percentage water-soluble arsenic pentoxide caused the aphids to increase. Both calcium arsenates caused larger increases in aphid population than the synthetic cryolite. Using yields as the criterion, all insecticides were equally effective.

Experiment 2.—The natural cryolite-sulfur mixture and the lead-arsenate-clay mixture gave better control of bollworms than the commercial calcium arsenate. The arsenicals were equally effective against the weevil and both produced significantly better control than that obtained from the cryolite mixture. The commercial calcium arsenate caused larger increases in aphids than either the lead arsenate or the cryolite, indicating again

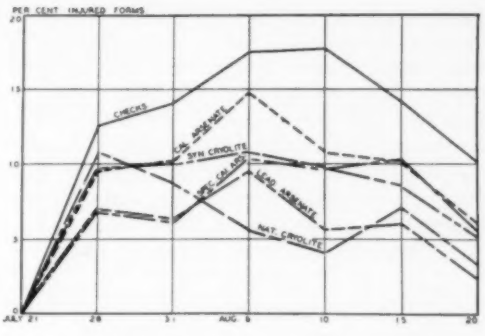


FIG. 1.—The average percentage of bollworm injured forms on groups of plats receiving treatments as indicated.

that the higher percentage of water-soluble arsenic pentoxide caused larger increases in aphids. Commercial calcium arsenate gave better control of rapid plant bugs than either lead arsenate or natural cryolite, indicating that the water-soluble arsenic pentoxide is important in the control of these bugs. As indicated by the yields, lead arsenate and commercial calcium arsenate were equally effective. The difference in yield between lead arsenate and cryolite-sulfur was significant. The low yield on the plats treated with cryolite-sulfur were caused by the poor weevil control obtained from this insecticide. The aphid and rapid plant bug population had little, if any, effect on the yields.

Since these two experiments were located in the same cut and the infestations and yields on the checks and commercial calcium arsenate treated plats of the respective experiments were so nearly the same, comparisons can be made of all insecticides (Fig. 1). These comparisons indicate that lead arsenate and natural cryolite were more effective against bollworms than calcium arsenate or synthetic cryolite. All arsenicals were more effective against the weevils than the cryolite. The arsenicals containing the highest percentage of water-soluble arsenic pentoxide caused the largest increases in aphids but gave the best control of rapid plant bugs.

SUMMARY.—The two experiments located in the same cut were conducted at College Station, Texas, for bollworm control. These experiments were designed to compare the effectiveness of synthetic and natural cryolite, lead arsenate, commercial calcium arsenate, and a special calcium arsenate containing a high percentage of water-soluble arsenic pentoxide

when used against the bollworm. Records of the infestations of weevils, rapid plant bugs, and aphids that developed on the plats made it possible to obtain some information on the action of the insecticides on these pests also. Lead arsenate and natural cryolite-sulfur (85–15) gave better control of the bollworm than the calcium arsenates or synthetic cryolite-sulfur (85–15). All arsenicals were more effective against the weevils than the cryolites. The arsenicals containing the highest percentage of water-soluble arsenic pentoxide caused the largest increases in aphids, but gave the best control of the rapid plant bugs. In general the plats treated with arsenicals yielded more cotton than the plats treated with cryolites, because the cryolites did not give adequate control of the boll weevil.—2-17-41.

LITERATURE CITED

Gaines, J. C. 1937. Tests of insecticides for cotton boll weevil and bollworm control using the Latin square plat arrangement and analysis of variance. JOUR. ECON. ENT. **30**(5): 785–90.

Gaines, J. C. 1939. Insecticide tests for bollworm control during 1938. JOUR. ECON. ENT. **32**(6): 821–4.

Gaines, J. C. 1940. Tests of insecticides for certain cotton insects during 1939. JOUR. ECON. ENT. **33**(4): 684–8.

Moreland, R. W. 1938. Recent field tests of insecticides for control of the cotton bollworm. JOUR. ECON. ENT. **31**(6): 666–8.

Moreland, R. W., and F. F. Bibby. 1931. Field tests in Texas of insecticides for control of the cotton bollworm (*Heliothis obsoleta* Fabr.). JOUR. ECON. ENT. **24**(6): 1173–81.

Moreland, R. W., and J. C. Gaines. 1939. Insecticide tests for the control of the cotton bollworm in 1936. JOUR. ECON. ENT. **32**(1): 104–6.

Control of the Flea Beetle, *Phyllotreta vittata discedens* Weise[1] in the Texas Gulf Coast

M. J. JANES, *Texas Agricultural Experiment Station, Alta Loma*

The flea beetle, *Phyllotreta vittata discedens* Weise, is an important factor limiting the production of mustard, turnips, and similar crops in the Gulf Coast of Texas. Injury occurs mainly during a restricted period extending from April to June. Occasional infestations are encountered later in the summer. Damage consists in some cases of complete destruction of small seedlings by the adults; in other cases numerous feeding punctures in the leaves result in a reduction of the market value of the mature plants. Control experiments on the adult beetles on mustard have been conducted by the Texas Agricultural Experiment Station, at Alta Loma, Texas, during the summers of 1938, 1939, and 1940, using pyrethrum-sulphur and cubé-sulphur dusts.

Roney[2] found a dust composed of 325-mesh conditioned dusting sulphur and cubé, containing 0.4 per cent rotenone in the finished insecticide, to give satisfactory control. He conducted two experiments, one employing four plats and the other three plats. Proprietary brands of concentrated pyrethrum combined with sulphur to produce dusts containing 0.1 per cent pyrethrins failed to give adequate control. Combined dusts containing 0.075 per cent pyrethrins and 0.4 per cent rotenone gave but slightly better control than dusts containing only the rotenone.

In an experiment conducted by the writer in May, 1939, two different dusted plats and an untreated check were each replicated 4 times in randomized blocks, making a total of 12 plats. Each plat was one-fifty-sixth acre in area, containing 10 rows 34.5 feet long. One of the dusts was composed of 325-mesh conditioned dusting sulphur and pyrethrum powder, and contained 0.1 per cent pyrethrins in the finished insecticide. The other dust was composed of 325-mesh, conditioned dusting sulphur and cubé, and contained 0.5 per cent rotenone in the finished product. Five dust applications were made at the rate of 30 pounds per acre per application. The dusts were applied early in the morning, beginning as soon as it was light enough to see clearly. The results of this experiment were analyzed by the method of analysis of variance as described by Snedecor (1937). The data is presented in

[1] Identification checked by H. J. Reinhard, Texas Agricultural Experiment Station.

[2] Unpublished data, 1938. Texas Agr. Expt. Station.

tables 1 and 2. On the basis of injury per unit area of plant surface as determined by the number of holes per square inch at maturity the variation produced by differences in treatments was highly significant. The cubé dust gave significantly better control than the pyrethrum. There was no significant difference between the condition of the plants on the untreated check and the pyrethrum-sulphur dusted plats.

Table 1.—Plat arrangement and plant injury in the randomized blocks for the test of insecticides in the control of the flea beetle, *Phyllotreta vittata discedens* Weise, during 1939.

A	P	R
2.66	1.48	.30
P	R	A
1.60	.20	1.61
R	A	P
.18	1.10	1.89
A	R	P
2.63	.33	2.79
	Treatment Averages	
A	P	R
2.00	1.94	.25

The figure in each plat represents the average number of holes per square inch on 100 square inches of mustard leaf surface examined at harvest time.
A—untreated P—pyrethrum-sulphur R—cubé-sulphur

The 1940 experiment was similar to that of 1939 with the exception that concentrated pyrethrum dust was used in the pyrethrum-sulphur mixture. The finished dust contained 0.1 per cent pyrethrins. The rotenone content of the cubé-sulphur was increased slightly to 0.55 per cent, and the number of replications was increased to six, making a total of 18 plats. Four dust applications were made, averaging approximately 25 pounds per acre per application. The infestation developed so early and was so severe that many of the tiny seedlings were completely destroyed and the analysis of the comparative control was based on the plant survival. The data is presented in tables 3 and 4. The variation produced by differences in treatments was highly significant. There was a significant difference in plant survival between either series of dusted plats and the check; there was no significant difference in the effectiveness of the two dusts.

Table 2.—The analysis of variance of flea beetle injury in the insecticide test during 1939.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Total	11	10.7364	—
Blocks	3	1.3816	.4605
Treatments	2	7.8733	3.9366*
Remainder	6	1.4815	.2469

* Highly significant.
The difference between treatment means required for significance is .86 hole per square inch.

Table 3.—Plat arrangement and plant survival in the randomized blocks for the test of insecticides in the control of the flea beetle, *Phyllotreta vittata discedens* Weise, during 1940.

A	D	R
56.1	84.0	84.3
A	D	R
26.6	66.7	54.5
D	R	A
55.7	61.9	3.9
A	D	R
5.0	54.7	89.9
R	A	D
61.9	2.4	42.8
D	A	R
39.2	3.8	55.5
	Treatment Averages	
A	D	R
16.3	57.2	68.0

The figure in each plat represents the final plant count at the end of the test expressed as a per cent of the initial plant count made at the beginning of the experiment. Plant counts were made on 88 feet of row, the identical area being examined at the beginning and the end of the experiment.
A—untreated D—pyrethrum-sulphur R—cubé-sulphur

Table 4.—The analysis of variance of plant survival in the insecticide test during 1940.

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE
Total	17	13750.28	—
Blocks	5	3470.02	694.00
Treatments	2	8922.67	4461.34*
Remainder	10	1357.59	135.76

* Highly significant.
The difference between treatment means required for significance is 14.99.

These experiments indicate that a cubé-sulphur dust containing 0.4 per cent or more rotenone will effectively control the flea beetle, *Pyllotreta vittata discedens* Weise, in the Texas Gulf Coast. Dusts containing pyrethrum apparently are less effective than those with cubé.—2-11-41.

LITERATURE CITED

Snedecor, G. W. 1937. Statistical methods—applied to experiments in agriculture and biology. Collegiate Press, Inc., Ames, Iowa.

Rate of Application of Derris-Talc Dusts for Pickleworm Control

F. S. Arant, *Alabama Agricultural Experiment Station, Auburn*

Preliminary experiments conducted in 1938 and 1939 (Arant 1940) indicated that heavy applications of 1 per cent rotenone dusts were effective in controlling the pickleworm, *Diaphania nitidalis* (Stoll) and melonworm, *D. hyalinata* (L), in cantaloupes, but the effect of different rates of application was not determined. In 1940, additional experiments were conducted with derris-talc dusts containing 1 per cent rotenone applied at rates varying from 12.5 to 42.5 pounds per acre per application. The cantaloupes were planted late in the season because pickleworm damage is most severe during mid-summer. Melonworm damage is also frequently severe in a late crop, but was not a factor in 1940. The results of the 1940 experiments are reported herein.

Procedure.—The experiments were conducted on 25 one-fortieth-acre plots, each 36.3 feet wide and 30 feet long. Six rows approximately 6 feet apart were laid off on each plot and 6 hills of cantaloupes 5 feet apart were planted in each row. Alleys at least 30 feet wide were left between plots to adequate protection from drifting dust. Each treatment occurred on 5 plots distributed at random in 5 blocks.

The experiments were conducted on Norfolk soil, low in fertility. The soil received commercial 6-8-4 (N-P-K) fertilizer at the rate of 1200 pounds per acre. The fertilizer was divided equally among the cantaloupe hills and was mixed thoroughly with the soil. Hale's Best cantaloupes were planted May 25 but as a result of a heavy rainfall only about one-fourth of a stand was obtained. The missing hills were replanted June 8 and again July 1. Considerable numbers of the germinating seed of these plantings were eaten by field mice. Rabbits also caused severe damage to the foliage on some plots. As a result of the difficulties in obtaining a stand, plants of three ages were present on most plots. On only one plot (No. 1) was there obtained a perfect stand from the first planting. A perfect stand never was obtained on 15 plots.

A mixture of derris, talc, and wheat flour, 5-14-1[1], was applied on 3 series of plots, A, B, and C. In series A, 5 applications of 12.5 pounds per acre were made on plots 1, 6, 11, 16 and 21. Because of the increased size of the plants the rate was then increased to 17.5 pounds per acre for 4 applications, making an average rate of 14.7 pounds per application. In a similar manner the dust was applied to plots, 2, 7, 12, 17 and 22 (series B) at the rates of 20 and 30 pounds for an average of 24.4 pounds per acre per application. In series C, the dust was applied to plots 3, 8, 13, 18 and 23 at the rates of 27.5 and 42.5 pounds per acre for an average of 34.2 pounds per application. Plots 4, 9, 14, 19 and 24 received a mixture of derris, talc, flour, and *Cuprocide*, 25-64-5-6*, at the same rate as those in series B. Plots 5, 10, 15, 20 and 25 were not dusted.

All dusts were applied with a plunger-type hand dust gun. The correct amount of the insecticide was placed in the gun and then distributed uniformly by dusting lightly over the plot several times until the gun was empty. No allowance was made for wastage. Dustings were made at any time of day, provided the air was calm. The first application was made July 22 when the first fruits were set and additional ones at 4- to 7-day intervals until August 29 when the ninth dusting was made. Five of the applications were followed by rainfull in 26 to 36 hours.

Control of the insect was determined by harvesting the fruits as they matured and examining them for infestation. Rotting melons were also picked and examined. Harvests were made at intervals of 1 to 7 days from August 9 to September 20, but most of the crop matured between August 23 and September 5.

Results and Discussion.—All dusting treatments were effective in controlling the pickleworm (Table 1). The derris-talc dust, applied at the average rate of 14.7 pounds per acre per application appeared to be slightly less effective than the same dust applied at rates of 24.4 and 34.2 pounds per acre. Analysis of variance based on the number of edible fruits per

[1] Parts by weight.

Table 1.—The effectiveness of various rates of application of 1 per cent rotenone dusts in pickleworm control in cantaloupes.

INSECTICIDE AND RATE PER APPLICATION[1]	MEAN NO. MELONS PER PLOT[2]	MEAN PER CENT		MEAN NO. EDIBLE MELONS	
		Melons Infested	Control of Insect	Per Plot	Per Acre
Derris-Talc-Flour, 5–14–1; 14.7 lbs. Per A.	96.4	16.3	83.1	80.0	3200
Derris-Talc-Flour, 5–14–1; 24.4 lbs. Per A.	90.2	7.4	92.3	83.4	3336
Derris-Talc-Flour, 5–14–1; 34.2 lbs. Per A.	77.2	5.6	94.2	72.8	2912
Derris-Talc-Flour-*Cuprocide*, 25–64–5–6; 24.4 lbs. Per A.	88.2	6.1	93.7	83.6	3344
None (Check)	50.6	96.5		2.4	96

[1] Nine applications were made.
[2] Five plots of each treatment.

plot, however, revealed that only differences of 18.2 or above were significant. Thus, it is evident that the only significant differences were those between the dusted and undusted plots. Cantaloupes dusted with *Cuprocide* retained their foliage longer than other plants and the maturity of fruit was delayed slightly.

The heavy rates of application of rotenone dusts appeared to reduce the yield slightly when compared with yields on plots dusted at the 14.7 pound rate. A similar indication was noticed in 1939 when the total yields from plots dusted with 1 per cent rotenone were slightly lower than those from plots receiving 0.5 per cent rotenone dusts (Arant 1940). An analysis of variance was made on the total fruits produced per plot in 1940. The significant difference between means of treatments was found to be 20.7. The mean difference in yield between plots receiving 14.7 and 34.2 pounds of dust per acre was 19.2. This difference approaches significance and the indications are that excessive amounts of rotenone reduced the yield, although clear-cut statistical proof is lacking. All dusted plots produced significantly more melons than the check plots.

The low yields on the check plots resulted from the destruction of young melons by pickleworms and from a heavy infestation of aphids which caused the plants to die prematurely. Most of the melons harvested were riddled with pickleworm larvae. Five to fifteen larvae per fruit were not uncommon and in one instance 30 were found in a single cantaloupe. On the dusted plots, the few melons which were infested rarely ever had more than 1 or 2 larvae.

Although the cantaloupes were grown late in the season, most of the fruits were of excellent quality. The melons maturing in August and the first few days of September were of especially high quality. Dry weather in September caused the foliage to drop about September 15 to 20, leaving a considerable number of melons which turned yellow without really ripening.

SUMMARY.—Nine applications of a derris-talc-flour dust, containing 1 per cent rotenone, were effective in controlling the pickleworm in late cantaloupes on one-fortieth-acre plots. Applications at the average rate of 34.2 pounds per acre were not significantly more effective than those at the rate of 14.7 pounds per acre. There were strong indications that the higher rate of dusting reduced slightly the yield of melons, but clear-cut statistical proof of the reduction was lacking. A mixture of derris, talc, flour, and *Cuprocide*, 25-64-5-6, was no more effective in controlling the pickleworm than the derris and talc, but caused the plants to retain their foliage longer and also slightly retarded maturity. An average of 3200 edible melons per acre was produced on 5 plots dusted with derris and talc as compared with an average of 96 edible melons per acre on the 5 check plots.—4-21-41.

LITERATURE CITED

Arant, F. S. 1940. A Progress Report on the use of Rotenone Dusts for the Control of the Pickleworm and the Melonworm in Alabama. JOUR. ECON. ENT. **33**(6): 840–3.

Control of Borers on Recently Top-Worked Pecan Trees

W. C. Pierce and C. B. Nickels,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Introduction.—The American plum borer, *Euzophera semifuneralis* (Walk.), and the pecan borer, *Conopia scitula* (Harr.), often cause severe injury to recently top-worked pecan trees. Frequently larvae of the two species may be found feeding closely together on the same tree. The absence of a practical method of control aroused the junior writer's interest in the problem in 1931. Observations were made relative to the types of borer injury, the relation of orchard practices to their abundance, and the seasonal life history of the borers. This paper gives the results of biological studies and control experiments conducted in central Texas during the years 1932 to 1939.

Nature of Injury to Pecan Trees.—The larvae of both species of borers feed chiefly on the inner bark and sapwood. Much of the cambium and callus around new grafts may be destroyed (Fig. 1). The larvae frequently attack the cambium of the scion and stock through cracks in the grafting wax (Fig. 2). A weak union of scion and stock often results from the feeding of the larva, and wind may blow the scion from the tree. Borer larvae may injure or destroy either grafts (Fig. 3) or patch buds, the former being destroyed more frequently than the latter. In an orchard at Gustine, Texas, in 1933 approximately two-thirds of 1,200 grafts and one-third of 3,000 patch buds placed on pecan trees were destroyed by borers.

Borer larvae also cause much damage by girdling the basal portions of sprouts that have been previously patch-budded. In an orchard near Brownwood, Tex., in 1932 a total of 322 out of 616 sprouts on 24 top-worked trees in 1 row were found to be infested by borers. Wind may blow girdled sprouts from the tree.

A tree is susceptible to borer attack from the time the top is removed until the growth tissues of the scion and stock have united.

Orchard Practices Favoring Borer Injury.—Certain operations in top-working native pecan orchards are favorable to the development of borers. The killing and felling of trees and the cutting back of branches on the trees prior to top-working are favorable to the development of borers. The severe cutting back of branches in preparation for top-working lowers the vitality of the trees and favors the development of borers. It has been observed that one or more generations of both species of borers may complete their development in stumps from felled trees and in girdles that are cut to deaden trees. The continuation of top-working operations in an orchard over a period of several years is also favorable to the maintenance of a heavy borer population.

During the past several years the waxes used by many of the pecan propagators in Texas to cover grafting wounds have been unsatisfactory. Cracks usually appear in the wax within a few days, and through these openings borer larvae may enter the graft wounds.

Observations on Biology.—Overwintering larvae of the American plum borer begin to pupate at Brownwood late in March, and moths of the overwintering generation emerge during April. Field observations have indicated that under favorable conditions five generations of this borer may develop in a year in central Texas. First-generation moths emerge late in May, and second-generation moths emerge approximately 1 month later. Larvae and pupae were collected from pecans in July, August, and September, but the number of generations which developed during that period was not determined.

Adults of the pecan borer begin to emerge early in April in central Texas. Records were obtained which showed that adults emerged in April, May, July, August, and September. The detailed life history of this insect is unknown, but published literature indicates only one generation a year.

In Texas mature larvae of the pecan borer have been taken from pecan, elm, and southern live oak. The American plum borer has been taken from the same species of trees and also from pin oak.

Paradichlorobenzene and Crude Cottonseed Oil.—Hamilton (1927) re-

[1] W. S. Price, of Gustine, Texas, cooperated in many of the experiments described in this paper.

ported good results from the use of 1 pound of paradichlorobenzene dissolved in 1 quart of soluble pine tar oil for the control of the American plum borer in linden trees. Snapp & Thomson (1931) successfully used 1 pound of paradichlorobenzene dissolved in 2 quarts of crude cottonseed oil for the control of the lesser peach borer on peach. This mixture was applied with a paint brush to borer-infested areas on 70 top-worked pecan trees near Brownwood March 9 to 16, 1932. A total of 24 trees were used as untreated checks. The trees were wormed between March 22 and April 3 to determine the results of the treatment. Of 298 larvae from the treated trees 86 per cent were found to be dead. From the untreated check trees 62 larvae were examined, and 26 per cent of them were dead.

During July, August, and September 1939 tests with paradichlorobenzene in crude cottonseed oil at the strength indicated above were conducted against the American plum borer and the pecan borer. The material was applied with a paint brush to and a few inches beyond the edge of borer-infested areas in bark wounds on the trunks of pecan trees. The results of these tests are shown in table 1.

The mortality in untreated trees was about 1 per cent. The treatment was effective in the control of larvae feeding in shallow burrows, but was less effective against larvae feeding in burrows that extended several inches beyond the point of entrance. Most of the larvae of the American plum borer, which predominated in the wounds, were observed to leave their burrows within 30 minutes after the application of the paradichlorobenzene wash. Contact with the insecticide usually resulted in the death of the larvae.

Table 1.—Results of experiments with paradichlorobenzene dissolved in crude cottonseed oil for the control of the American plum borer and the pecan borer, Gustine, Texas, 1939.

Date of Treatment	Date Larvae Were Examined	Total Larvae Examined	Per Cent Mortality
July 24	Aug. 4	142	68.3
Aug. 8	Aug. 24	102	89.2
Aug. 24	Sept. 7	122	68.9
Sept. 22	Sept. 22	178	86.0
Total or average	—	544	78.1

One disadvantage in the use of the paradichlorobenzene wash is the necessity of making one to three later examinations of the grafts to detect infestations of borers surviving the treatment, and to make further applications of the insecticide when necessary.

GRAFTING WAXES AND GRAFTING TO PREVENT BORER INJURY.—Shortly after the beginning of these experiments it was realized that most of the borer injury to scions could be eliminated by keeping graft wounds thoroughly covered with grafting wax until the scion and stock had formed a good union. In experiments conducted at Gustine during 1935, 1936, and 1937 a total of 643 bark grafts were covered with melted grafting wax which contained paradichlorobenzene at the rate of 1 teaspoonful to 1 pint of wax. It was necessary to examine the scions at 10-day intervals until the scion and stock had formed a good union and apply the grafting wax-paradichlorobenzene mixture on all cracks and borer-infested areas. That method of treatment prevented the loss of scions from borer attacks in the presence of a light infestation, but it required much labor.

In 1938 and 1939 studies were carried on at Brownwood and Gustine to determine the relative influence of two methods of grafting and of three wax mixtures on borer infestation of scions. Bark grafts and inlay-bark grafts of an improved type (Sitton 1940) were employed in the experimental work. The wax mixtures tested are as follows:

Mixture No.	Ingredients and Quantity in Pounds
1	rosin 4, beeswax 1, kieselguhr 1/2
2	rosin 5, beeswax 1, talc 1/2
3	rosin 2, beeswax 1, tallow 1/4

Four combinations of treatments were tested at Gustine in 1938 and three of these were duplicated at Brownwood. The results of these tests are shown in table 2.

Observations indicated that borer infestation of the scions was largely influenced by the continuity of the cover of grafting wax over the graft wounds. Scions were attacked by larvae that entered through cracks in grafting wounds and through areas of grafting wounds to which no wax was applied. The inclusion of paradichlorobenzene in the wax mixtures did not increase their effectiveness in protecting scions from borer infestation. In-

Table 2.—Results of experiments with wax mixtures, with and without paradichlorobenzene,[1] and methods of grafting for the control of the American plum borer and the pecan borer on top-worked pecan trees, 1938.

Wax Mixture	Grafting Method	Date Scions Were Set	Total Number of Scions	Percentage of Scions Infested			
				May 14–16	May 29–June 2	June 13–15	July 30–Aug. 4
		Gustine, Tex.					
No. 1	Inlay bark	Apr. 21	33	0	0	0	3.0
		May 3, 6, 9, 11	311	0	0.6	1.0	5.1
No. 1 plus Paradichlorobenzene	Inlay bark	Apr. 22, 26	80	1.3	7.5	7.5	16.3
		May 12	167	—	0	0	4.8
No. 3	Bark	Mar. 24, 31; Apr. 16	144	3.5	6.9	9.7	9.7
	Inlay bark	Apr. 16, 21	104	2.9	6.7	10.6	13.5
No. 3 plus paradichlorobenzene	Inlay bark	Apr. 22	67	6.0	17.9	25.4	34.3
		Brownwood, Tex.					
No. 1	Inlay bark	Apr. 27, 29	73	0	0	0	12.3
		May 4, 5	101	0	0	0	1.0
No. 1 plus Paradichlorobenzene	Inlay bark	May 3, 4	63	0	0	1.6	22.2
No. 3	Bark	Mar. 25	23	0	0	0	0
	Inlay bark	May 2	45	0	0	2.2	2.2

[1] Four grams (1 teaspoonful) per pint of grafting wax.

lay bark grafts had a larger area of tissue union between scion and stock and were found to be more resistant to destruction by borer larvae than bark grafts. By June 13 a good union had formed between the scions and stocks, and after that date borer infestations were of slight importance.

In 1939 a total of 1,795 scions were set on pecan trees at Gustine and Brownwood. Wax mixtures 1 and 2 were used with both ordinary bark grafting and inlay bark grafting. Paradichlorobenzene was added to wax mixture 1 and applied to a few of the inlay bark grafts at both locations.

A single thorough application of grafting wax at the time the grafts were set nearly eliminated borer injury. In four out of seven plots none of the grafts were infested by borer larvae, and in the other three plots the borer infestations did not exceed 1.2 per cent.

To obtain information relative to the abundance of the borer population in the Price Orchard at Gustine, and to test the efficiency of grafting wax in protecting wounds from borers under severe conditions, wounds 4 inches square were cut in surplus pecan trees and the bark was removed. Some of the tree wounds were covered with the grafting wax and others were used as untreated checks. The records of borer infestation in unprotected tree wounds and in wounds covered with grafting wax are given in table 3.

As shown in table 3, unprotected wounds on the trunks of pecan trees became severely infested by borers within a few weeks after they were made, whereas wounds properly covered with grafting wax were well protected.

Table 3.—Borer infestations in untreated wounds on pecan trees and in wounds treated with grafting wax mixture 2, Gustine, Tex., 1939.

Condition of Wound	Date Wounds Were Made	Number of Wounds	First Examination		Second Examination	
			Date	Percentage of Wounds Infested	Date	Percentage of Wounds Infested
Treated	July 6	38	July 20	0	Aug. 11	23.7
	July 20	90	Aug. 11	15.6	—	—
Untreated	Apr. 14	103	May 25	34.0	—	—
	May 25	224	June 16	65.6	—	—
	July 6	57	July 20	64.9	Aug. 11	89.5
	July 20	82	Aug. 11	87.8	—	—

DISCUSSION.—As a result of the work reported in this paper it is evident that in top-working pecan trees all wounds on scion and stock should be thoroughly covered with a grade of grafting wax that will maintain an unbroken cover until the graft has formed a good union. The inlay-bark graft method was found to be superior, because by this method the scions could be closely fitted to the stock and easily covered with wax. When the grafts become infested, or when the basal portion of patch-budded sprouts are attacked by borer larvae, the infested areas can effectively be treated with the paradichlorobenzene-crude cottonseed oil mixture, 1 pound of the chemical being dissolved in 2 quarts of the oil and applied with a paint brush.

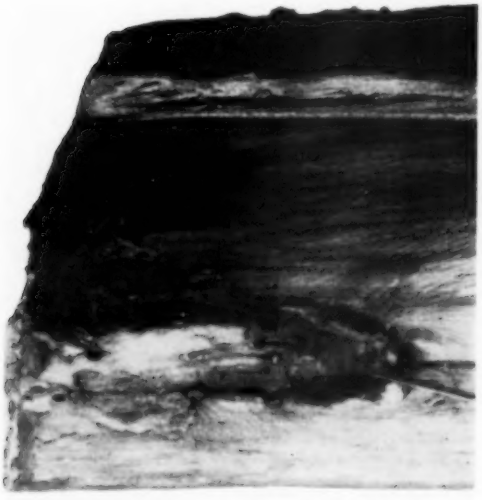


FIG. 1.—Pecan graft stock with scion removed, showing injury to callus by larva of the American plum borer, ×1.

In the top-working of pecan trees the branches should be cut back no more than is necessary. Severe cutting back of the branches lowers the vitality of the trees, which is favorable to the development of borers.

SUMMARY.—Observations were made relative to the seasonal life history and hosts of the American plum borer, *Euzophera semifuneralis* (Walk.), and the pecan borer, *Conopia scitula* (Harr.),

FIG. 2.—Inlay-bark graft on pecan attacked by larva of the American plumborer through crack in grafting wax, ×1.

which often cause severe injury to recently top-worked pecan trees. Pecan grafts and patch buds are destroyed by borer larvae feeding on the cambium and callus of the scion and stock. Most of the borer larvae enter graft wounds through cracks in the grafting wax. Patch budded sprouts are also often girdled by borer larvae and may then be blown from the tree by wind.

The inlay-bark graft method permitted the close fitting of scion and stock, which tended to reduce injury from borers. The best method of protecting scions from borer injury was to cover all graft wounds with a grade of grafting wax that would not crack until after the graft had formed a good union.

Paradichlorobenzene dissolved in crude cottonseed oil at the rate of 1 pound to 2 quarts of oil was effective in killing borer larvae in graft wounds.—4-7-41.

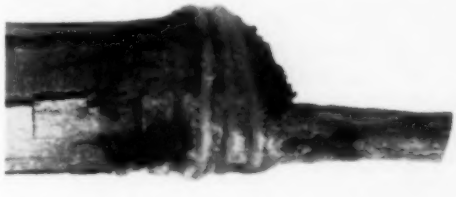


FIG. 3.—Bark graft on pecan destroyed by the larva of the American plum borer. ×1.

LITERATURE CITED

Hamilton, C. C. 1927. Some tests of para-dichlorobenzene dissolved in soluble pine tar creosote in the control of boring insects in living plants, N. J. Agr. Expt. Sta. Ann. Rpt. (1926) **39**: 196–9.

Sitton, B. G. 1940. Pecan grafting methods and waxes. U. S. Dept. Agr. Cir. **545**.

Snapp, Oliver I., and J. R. Thomson. 1931. The control of the lesser peach borer with paradichlorobenzene solutions. U. S. Dept. Agr. Cir. **172**.

The Life History of *Phyllophaga tristis* (F.)[1] and Allied Forms

H. J. REINHARD, *College Station, Texas*

Among the species of *Phyllophaga* recorded from the United States perhaps none covers the wide range of distribution that has been listed for *P. tristis*. Horn (1887) pointed out that a form so widely distributed might be expected to vary considerably, not only with respect to size and color, but also in sculpture. In reference to this conclusion it must be remembered that during Horn's time the importance of genitalic characters in separating species remained unknown. However, some of the variations which Horn noted between northern and southern specimens now may be associated with distinct differences in genitalic characters indicating the presence of forms entitled to at least subspecific rank in the *tristis* complex.

During the past two seasons biological studies on Texas *Phyllophaga* have included three forms of the *P. tristis* complex characterized as *tristis tristis*, *tristis amplicornis*, and *tristis apicata* (Reinhard 1939). Adults of these forms have the following characters in common: size small (10 to 14 mm. long); body above clothed with a vestiture of hairs; color pale yellowish to reddish brown; functional wings present in both sexes, and it may be added that all are nocturnal in habit.

The life history data recorded on the following pages were secured by rearing grubs individually in 4- and 6-ounce tin ointment boxes which were kept in a cellar where temperatures were not subject to wide or sudden fluctuations. As previously reported (Reinhard 1940) grapenuts proved quite satisfactory as a diet for developing grubs under conditions of close confinement, and rearings were again made by the use of this breakfast cereal as the principal source of food for each individual under observation.

Phyllophaga tristis tristis (Fabricius).—This species was originally described by Fabricius (1781) from "Boreal America." The type specimens probably came from some locality in the northeastern section of the country, and it appears likely that the common form of that region agrees most closely with the type series. In Texas, the typical form as considered above, is less commonly encountered than either of the others here under consideration. Collections made at lights in Nacogdoches, Texas, during March and April 1939 yielded about a dozen specimens. This is seemingly the first and sole record of occurrence in this State. Although apparently of no major economic importance locally, the present form was included in the rearing series for life history comparison with its more abundant southwestern allies.

Life Cycle.—A lot of 18 beetles, including 10 females, collected at Hope, Arkansas, April 3, 1940, was received on April 6 and immediately placed in an oviposition cage. The beetles fed readily upon the foliage of pecan, post oak, and elm. On May 10 only 1 female remained active and the entire lot had deposited a total of 272 eggs or at an average rate of slightly less than 1 egg per beetle day over the 34-day period. Reared individuals were not available for observation on oviposition, but it appears likely that under more favorable or natural conditions the total number of eggs laid per female may be considerably greater.

Egg.—The *tristis* forms, like other members of the genus, deposit their eggs separately in prepared cells within small clumps of soil from 2 to 6 inches beneath the surface. The newly deposited egg is

[1] Contribution No. 647 from Division of Entomology, Texas Agricultural Experiment Station, College Station, Texas.

pure white, elongate oval in outline, and averages a trifle more than 1 mm. in length. As embryonic development proceeds the egg becomes more or less spherical in shape, increases in size to a diameter of 2 or 2.5 mm., and the color becomes tinged with yellow. Several days before hatching the embryonic outline of the larva is visible through the transparent egg shell. When the larva is hatched only a thin transparent tissue remains of the original egg. Under laboratory conditions the remains of eggs were not eaten by newly hatched individuals.

A summary of the data recorded on the duration of the egg stage is presented in table 1. In an average daily mean temperature of about 64° F., the incubation period ranged from 22 to 31 days and averaged approximately 27 days over a period of observation extending from April 6 to May 26. All eggs were incubated in 4- and 6-ounce tin boxes containing moist sterilized sand.

Table 1.—Duration of egg stage, *Phyllophaga tristis tristis*, College Station, 1940.

Date Laid 1940	Number Larvae Observed	Incubation Period Days			Temp. Av. Daily Mean
		Max.	Min.	Wt. Av.	
Apr. 6–16	55	31	27	28.47	63.6° F.
Apr. 16–22	21	29	27	27.48	64.1
Apr. 22–26	41	30	24	26.93	64.3
Apr. 26–May 2	51	27	22	24.14	64.4
Average duration of incubation period				26.75	

Larva.—The newly hatched larva is very small and delicate; wholly white in color, but the head soon begins to turn pale brownish and within a day or two following the first ingestion of soil a dark or blackish area becomes visible in the apical part of the alimentary tract. The young grubs with access to suitable food grow very rapidly. Two molts occur during the active or feeding period and the bulk of the individuals attain full growth by the end of August. Pupation follows without any protracted period of quiescence.

The data secured on larval development are briefly summarized in table 2. The weighted average of all individual rearing records indicate that approximately 32 days are required for the first instar, 23 days for the second instar, and 65 days for the third instar. In other words, the duration of the larval stage averaged about 120 days. The period over which these rearings were made extended from May 8 to October 1, 1940. Temperatures which affected the developing grubs ranged from 64° to 75° F., and averaged 70.5° F. over the entire period of observations.

Pupa.—After the larva has attained full growth it ceases to feed and becomes quiescent. Preparation for transformation to the pupa is manifested by voiding the characteristic blackish contents of the larval alimentary tract, after which the body becomes limp and slightly contracted. The duration of the prepupal stage is variable but usually does not exceed 4 or 5 days. The newly transformed pupa is pure white but soon turns to a light or yellowish brown, which gradually darkens to the color of the adult as the latter becomes visible through the pupal skin shortly prior to emergence. In size the pupa varies slightly ranging from 12 to 14 mm. in length and 6 to 8 mm. in width. Pupation occurs within a tubular smooth-walled cell prepared during the active period of the mature larva from 3 to 8 inches beneath the surface of the soil. First pupation was noted on August 31, the last on October 1.

Data on the duration of the pupal stage are presented in table 3. Briefly summarized these records indicate that the duration of the pupal stage varies from 18 to 24 days and that the weighted average is about 21 and 22 days for male and female,

Table 2.—Duration of larval stage, *Phyllophaga tristis tristis*, College Station, 1940.

Instar	No. of Larvae Observed	No. of Larvae in Instar for Period Specified					Weighted Average Days
		17–29 days	30–44 days	45–59 days	60–74 days	75–82 days	
First	46	18	27	1			31.85
Second	35	30	5				22.97
Third	35		1	9	19	6	65.23
Total larval period							120.05

Table 3.—Duration of pupal stage, *Phyllophaga tristis tristis*, College Station, 1940.

Sex	No. of Pupae Observed	No. of Individuals in Pupal Stage for Days Specified						Weighted Average Days
		18	20	21	22	23	24	
Male	13	1	2	5	1	3	1	21.38
Female	20		1	9	2	7	1	21.90
Average duration of pupal period								21.64

respectively. In daily mean temperatures ranging from 66° to 75° F. and averaging 70° F., the total duration of the pupal stage for both sexes was approximately 22.5 days.

SUMMARY OF LIFE CYCLE.—The complete life cycle of *Phyllophaga tristis tristis* may be summarized as follows: The beetles begin to emerge during the latter part of March and early April and remain active to about the middle of May. Oviposition in the laboratory was recorded from April 8 to May 16. About 27 days are required for the eggs to hatch. The larvae feed over a period of about 4 months and the bulk of a generation reaches maturity by the end of August. Pupation follows shortly thereafter and pupae are commonly present throughout September. Transformation to the adult requires 22 or 23 days and emergence from the pupal stage reaches maximum numbers during October. However, the adults remain within the pupal cells throughout the winter and normally do not emerge until the following March or April to complete a one-year life cycle. The actual time required from egg to adult in a generation is only 169 days, which may be apportioned among the developmental stages about as follows: egg 27 days; larva 120 days; pupa 22 days.

Phyllophaga tristis amplicornis Reinhard.—Biological studies on this recently characterized form were begun in 1939 and continued throughout 1940. It appears to be the predominant form in North-Central Texas and extends less abundantly southward in the State to Bexar and Atascosa Counties. In the male sex the long antennal club is characteristic and usually distinguishes it from the other forms here under discussion, but the principal distinctive item is the peculiar flattened apical process of the internal genital sac. Little or nothing is known concerning the economic importance of the larval stage in *P. tristis amplicornis*. Heavy flights of beetles were recorded in Erath County during April 1940, and adults were also commonly reported during the two previous seasons from the same county. It therefore appears likely that the larvae may occur in sufficient numbers to become a factor of economic importance, at least in local areas, during seasons of favorable climatic conditions. Available records indicate that the beetles feed most commonly upon the foliage of oak, pecan, and elm.

Table 4.—Number of eggs laid by reared adults of *Phyllophaga tritis amplicornis*, College Station, 1940.

Date 1940	Number of Eggs Laid							
	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6	Pair 7	Pair 8
3/28	P	P	P					
4/3	0	0	0	P	P	P	P	P
4/8	0	0	7	0	16	14	0	0
4/17	0	41	0	15	4	42	25	24
4/22	24	8	0	9	13	14	23	21
4/28	19	11	13	6	23	21	21	6
5/2	0	3	14	2	9	8	0	0
5/7	0	0	10	0	0	3	8	1
5/12	0	0	0	1	8	5	4	0
5/16	4	0	0*	0	0	0*	0	0
5/2	0	0		0*	0*		0	0*
5/29	0*	0*					0*	
Total	47	63	44	33	73	107	81	52

P—paired *—female dead.

Life Cycle.—The egg, larva, and pupa of this and the following form agree quite closely with the corresponding stages discussed under *P. tristis tristis*. To avoid profitless repetition descriptive items previously listed are omitted from the following discussions of the developmental stages.

Table 5.—Duration of egg stage, *Phyllophaga tristis amplicornis*, College Station, 1940.

Date Laid 1940	Number Larval Hatched	Incubation Period Days			Temp. Av. Daily Mean
		Max.	Min.	Wt. Av.	
Apr. 1–16	321	38	27	32.87	64.0
Apr. 17–22	183	30	26	27.68	64.1
Apr. 22–28	383	33	23	27.33	64.4
Apr. 28–May 3	554	32	22	24.89	64.5
May 2–7	152	26	19	24.16	64.5
May 7–12	128	23	19	21.48	64.8
Average duration of incubation period				26.40	

Egg.—Oviposition records in 1940 were secured from adults reared during the previous season. At the outset of the active or flight period 8 pairs of beetles were placed separately in oviposition cages and the number of eggs laid by each female, at 5- to 7-day intervals, is shown in table 4. The total number of eggs recorded per female ranged from 33 to 107 and the average was slightly over 62 eggs per pair. Under laboratory conditions the oviposition period extended from April 8 to May 16.

The minimum, maximum, and average duration of the egg stage as recorded in 1940 are indicated in table 5. Similar records secured in 1939, including 82 eggs incubated under higher temperatures, varied from 16 to 27 days and averaged about 20 days.

Larva.—The data accumulated on larval development of this form are briefly summarized in table 6. Out of a total of 594 newly hatched larvae isolated for rearing observations, 514 individuals were carried successfully to the third or final instar. The larger initial number of larvae was selected for the purpose of securing factual evidence to illustrate that white grubs may be reared in almost any desired numbers under conditions of close confinement.

The total time required for larval development is about 121 days, as compared with 120 days for the typical form shown in table 2. Growth in the first two larval stages, particularly in the second, is rapid, but the rate decreases in the final stage, which exceeds the combined length of the two preceding. Observations on larval development extended from May 6 to October 12, 1940. During this time the effective mean temperatures ranged from 64° to 75° F., and averaged nearly 71° F. over the entire period.

Pupa.—Data on the duration of the pupal stage, summarized in table 7, include records on 501 individuals as compared with 594 larval records. It should be stated that 33 larvae and pupae were preserved and that the remaining difference resulted from mortality during development. The time required for pupal development was found to vary from 17 to 28 days and averaged about 23 days for both sexes. In this study the period of observation on the pupal stage extended from August 27 to November 5, and the daily mean temperatures averaged 70° F.

SUMMARY OF LIFE CYCLE.—The complete life cycle of a generation of *P. tristis amplicornis* is essentially the same as in the typical form. The beetles normally emerge in maximum numbers during April and stragglers may remain active until June. Oviposition begins shortly after emergence of the beetles and approaches a peak by the end of April. About 26 days are required for incubation of the eggs. The larvae feed over a period of about 120 days and attain maturity in numbers by early September. Transformation to the pupal stage occurs commonly during the same month. The aver-

Table 6.—Duration of larval stage, *Phyllophaga tristis amplicornis*, College Station, 1940.

Instar	No. of Larvae Observed	No. of Larvae in Instar for Period Specified					Weighted Average Days
		14–29 days	30–44 days	45–59 days	60–74 days	75–89 days	
First	594	278	314	2			30.36
Second	591	512	79				21.21
Third	514			56	333	125	69.40
Total larval period							120.97

Table 7.—Duration of pupal stage, *Phyllophaga tristis amplicornis*, College Station, 1940.

Sex	No. of Pupae Observed	No. of Individuals in Pupal Stage for Days Specified												Weighted Average Days
		17	18	19	20	21	22	23	24	25	26	27	28	
Male	252		2	2	16	32	50	55	47	31	16	1		22.92
Female	249	2	2	4	11	30	60	67	48	23			1	22.65
Average duration of pupal stage														22.78

age time consumed in the pupal stage is approximately 23 days, so that emergence of adults from the pupa becomes general during October. The newly transformed beetles remain in the pupal cells to pass the winter and do not emerge until the following March or April to complete a one-year life cycle.

Among the species of Texas *Phyllophaga* so far studied the *tristis* forms here included are unique in completing egg to adult development within a period of less than 6 months. As here determined the actual time required in the developmental stages of *P. tristis amplicornis* is 170 days, which may be allocated about as follows: egg 26 days; larva 121 days; and pupa 23 days.

Phyllophaga tristis apicata Reinhard.—This form extends northward from the Gulf States to Kentucky and Maryland. In Texas, its range appears restricted to the humid eastern section of the State. The adult averages a little smaller in size than either of the forms discussed above, but the most reliable distinguishing character in the male sex is the thick outwardly tapered apical process of the internal genital sac. There is no information available concerning the economic importance of the present form. However, field examinations, which were made during February and March 1940, disclosed moderate to heavy populations of beetles in local fields of native grassland. The heaviest concentrations of overwintering beetles were found near stands of post oak, which seemingly is one of the preferred host plants. Beetles also have been observed feeding commonly upon the foliage of pecan and elm. Because of their small size, the adults consume less food than larger species and the damage resulting from the feeding activities is not very extensive. At least none of the complaints hitherto received of May beetles injuring foliage of trees has included specimens or evidence to implicate the present form.

Life Cycle.—The beetles secured in the field excavations mentioned above were utilized for observations on oviposition. These specimens, all taken prior to the beginning of the normal emergence period, were stored separately in 6-ounce containers until the first appearance of adults in the field. At this time, March 26, 1940,

Table 8.—Number of eggs laid by adults[1] of *Phyllophaga tristis apicata*, College Station, 1940.

Date 1940	Number of Eggs Laid									
	Pair 1	Pair 2	Pair 3	Pair 4	Pair 5	Pair 6	Pair 7	Pair 8	Pair 9	Pair 10
3/26	P	P	P	P	P					
4/1	0	0	0	0	0	P	P	P	P	P
4/8	0	10	0	0	11	0	0	0	0	0
4/17	7	7	0	0	6	7	0	0	17	0
4/22	13	23	16	8	21	10	13	0	19	21
4/28	0	11	9	18	18	12	20	16	28	13
5/2	0	0	7	4	16	8	0	12	16	4
5/6	0*	19	14	12	3	14	0	4	7	9
5/12		0	8	12	4	6	3	12	0	2
5/16		0*	0*	0	2*	1	1	8	0	0
5/22				0*		0*	0*	6	0	1
5/31								2	0	0
6/7								0*	0*	1
6/12										0*
Total	20	70	54	54	81	58	37	60	87	51

[1] Dug up in field prior to normal emergence period.
P—paired. *—female dead.

Table 9.—Duration of egg stage, *Phpllophaga tristis apicata*, College Station, 1940.

Date Laid 1940	Number Larvae Observed	Incubation Period Days			Temp. Av. Daily Mean
		Max.	Min.	Wt. Av.	
Apr. 1–8	93	37	31	33.28	63.6
Apr. 8–17	74	33	27	29.35	63.9
Apr. 17–22	81	29	26	27.84	64.1
Apr. 22–28	109	31	23	25.58	64.4
Apr. 28–May 2	45	27	23	23.78	64.4
May 6–12	15	21	19	19.87	64.7
Average duration of incubation period				26.62	

five pairs were placed separately in oviposition cages and five additional pairs were similarly caged about a week later. The data secured from these pairings are shown in table 8. Total egg production per pair ranged from 20 to 87 and averaged slightly over 57 eggs per pair. The period of egg-laying extended approximately from the first week in April to the first week in June.

hundred and twenty-two newly hatched larvae were isolated for individual records, and of this number 12 were preserved, and of the remainder 101 were reared to maturity from May 5 to September 30, 1940. During this period daily mean temperatures, in the cellar where the rearing work was done, averaged about 70° F. The time required for complete larval development was found to be 128 days, or about a week longer than for the same stage in either of the allied forms mentioned above. Development in the first two larval stages is quite uniform throughout these forms, and the greater differences in duration of the third stage are due, in part at least, to the inclusion of a variable prepupal stage.

Pupa.—Records on the duration of the pupal stage covering 101 individuals are summarized in table 11. The time required

Table 10.—Duration of larval stage, *Phyllophaga tristis apicata*, College Station, 1940.

Instar	No. of Larvae Observed	No. of Larvae in Instar for Period Specified					Weighted Average Days
		16–29 days	30–44 days	45–59 days	60–74 days	75–89 days	
First	122	34	87	1			31.76
Second	121	110	11				21.67
Third	101			5	36	59	74.46
Total larval period							127.89

Egg.—Records secured on the duration of the egg stage are summarized in table 9. These data indicate a wide fluctuation in the average time required for incubation of the egg. The period decreases progressively as the season advances even though temperatures are held at a practically constant level. In these observations, extending from April 4 to May 30, the average duration of the egg stage was found to be about 26.5 days; the minimum period recorded was 19 days and the maximum 37 days.

Larva.—A summary of the available data on larval development in *P. tristis apicata* is presented in table 10. One

for completion of pupal development ranged from 19 to 25 days and averaged about 22 days. This period closely approximates the corresponding stage as determined for each of the allied forms discussed above. There is no significant difference in the rate of pupal development between sexes. First pupation in this form was recorded on September 2, the last on October 25. During this period the effective daily mean temperatures averaged 70° F.

SUMMARY OF LIFE CYCLE.—The history of a generation of *Phyllophaga tristis apicata* is similar to that of its allied forms. Beetles begin to emerge in numbers early

Table 11.—Duration of pupal stage, *Phyllophaga tristis apicata*, College Station, 1940.

Sex	No. of Pupae Observed	No. of Individuals in Pupal Stage for Days Specified							Weighted Average Days
		19	20	21	22	23	24	25	
Male	52	1	2	5	21	19	4		22.29
Female	49		1	4	27	11	5	1	22.37
Average duration of pupal stage									22.33

in April, and oviposition continues over a period of 6 or 8 weeks. About 26 days are required for the eggs to hatch. Following a feeding period of a little more than 4 months, larvae are commonly mature by September, and the major portion of the brood pupates during the same month. Pupal development is completed in about 3 weeks so that newly transformed adults of a current generation are commonly present during October. The latter pass the winter in the pupal cells and emerge the following spring to complete a one-year life cycle. As determined in the laboratory, the actual time required for completion of the life cycle is about as follows: egg 27 days; larva 128 days; and pupa 22 days.—1-17-41.

LITERATURE CITED

Fabricius, J. C. 1781. Species Insectorum, I: 39.

Horn, Geo. H. 1887. Revision of the Species of *Lachnosterna* of America North of Mexico. Trans. Amer. Ent. Soc. **14**: 209–96.

Reinhard, H. J. 1939. New and Little Known *Phyllophaga* from Texas. Jour. Kans. Ent. Soc. **12**: 47–63.

Reinhard, H. J. 1940. The Life History of *Phyllophaga lanceolata* (Say) and *Phyllophaga crinita* (Burmeister). JOUR. ECON. ENT. **33**: 572–8.

Two Buprestid Cane-Borers of Brambles with Experiments on Control[1]

F. G. MUNDINGER, *New York State Agricultural Experiment Station, Geneva*

There are several species of insects that may be found boring in the canes of brambles in New York State. Two of these belonging to the family Buprestidae or flat-headed borers are discussed in this paper. They are *Agrilus ruficollis*, Fab., the red-necked cane-borer, and *Agrilus rubicola*, Abeille, which we propose to call the bronze cane-borer. The former has long been known to attack raspberries and blackberries and to it has been ascribed all of the characteristic cane injury mentioned below, *A. rubicola* having been completely overlooked as a raspberry pest. In 1938 when these studies were begun, *A. rubicola* was bred in considerable numbers from raspberry canes. The injuries resulting from its feeding during both the adult and larval stages were found to be indistinguishable from those caused by *A. ruficollis*. The two species were observed in widely separated plantings, sometimes one and again the other being predominant.

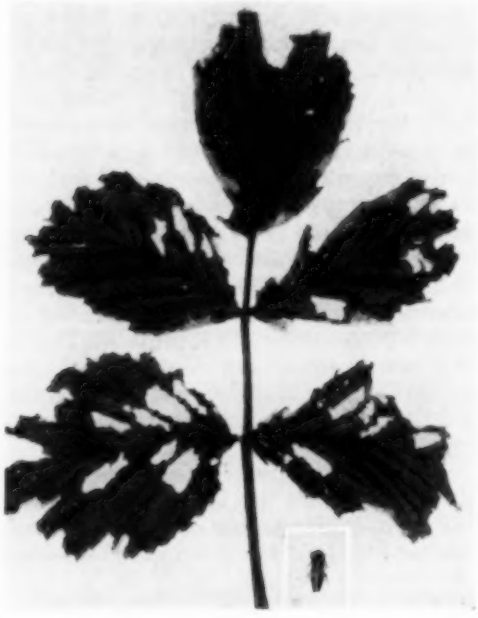


FIG. 1.—Raspberry foliage showing feeding by *Agrilus rubicola* (beetle shown in inset).

DESCRIPTION OF INSECTS.—*Agrilus ruficollis* (Fig. 2) and *A. rubicola* (Fig. 3) are very much alike in life-history and habits so that for all practical purposes the two species may be considered as one. The beetles are similar in size and shape, the length being about three times the greatest width. Specimens of *A. ruficollis* varied in length from 7.3 mm. to 5.4 mm. and in width from 2.3 mm. to 1.5 mm. The largest specimens of *A. rubicola* measured about 6.9 mm. in length and the smallest 4.6 mm. These ranged in width from 2.4 mm. to 1.4 mm. respectively. As is usual

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 411, December 10, 1940.

in this genus, the males are smaller than the females. The head as seen from above is bluntly rounded anteriorly. The pronotum is wider than long, the dorsal and lateral aspects of the anterior margin extending slightly over the base of the head are closely applied to it. The elytra are about as wide as the pronotum, gradually tapering toward the posterior end. The antennae and legs are short, the former, serrate. *A. ruficollis* is uniformly black in color except for the pronotum which varies from bright red to dark green and the head which has a bronze cast. *A. rubicola* is uniform in color but this varies from a bright coppery hue to an iridescent green in some individuals. The larvae (Fig. 2) of both species are white, the largest specimens measuring 20 mm. in length and the shortest 10 mm. The body is compressed dorsoventrally and the constrictions between the segments, especially those of the thorax, are very pronounced. The small, brownish head is retractable and can be drawn into the greatly expanded first thoracic segment. A pair of brown, forceps-like structures is present at the posterior of the last segment.

INJURY.—Many varieties of raspberries and blackberries were found to be attacked by the beetles. Rose canes having the familiar malformations commonly found on raspberries injured by *Agrilus ruficollis* were observed to be infested with *A. rubicola*. Thirty-six of fifty-seven varieties of raspberries in one station planting were attacked by the borers. Thorny varieties appeared to be more attractive to the beetles than those with smoother canes.

Two types of injury are observed on raspberry; that resulting from the adults feeding on the foliage, and the more familiar mutilations caused by the tunneling of the larvae in the canes. These insects seem fond of the sunshine, frequenting the upper leaf-surfaces through which they may gnaw irregular holes. Often times feeding is begun at the margin of the leaf and continues until the midrib is reached. In plantings where the beetles are abundant this leaf injury may be so severe as to give the foliage a ragged appearance (Fig. 1). Injury to the canes is the more important economically since it is the new growth, which is to bear the crop for the following year, that is damaged. The first indication of borers in the canes, particularly the smaller or less vigorous ones, is the wilting and dying of the foliage. Following this condition, the affected cane when subjected to strain such as that caused by wind may break off, the severed

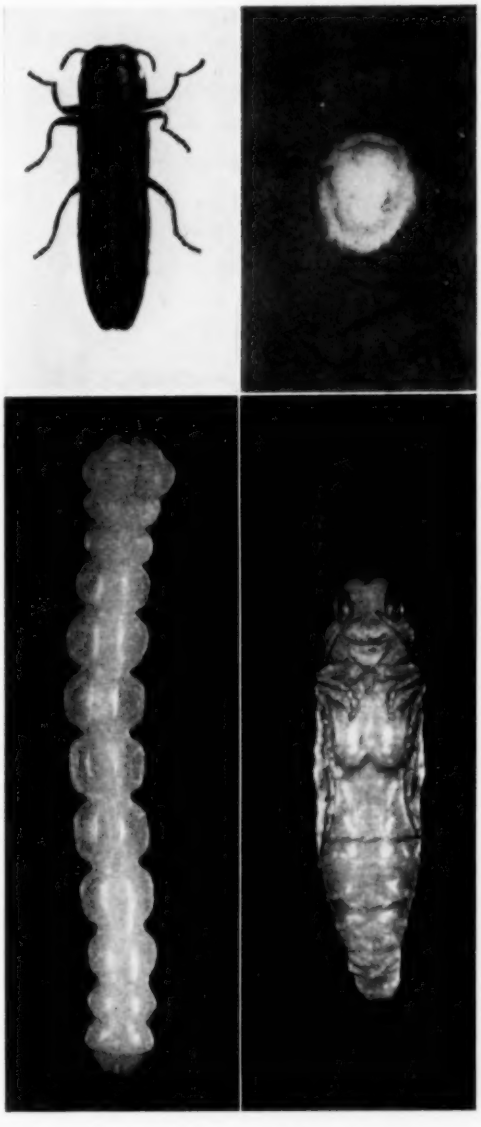


FIG. 2.—Stages of *Agrilus ruficollis*.—Above, adult (×6) and egg (×10); below, larva and pupa (×7).

ends appearing as if cut by a sharp knife. Some bushes in heavily infested plantings may have every cane cut in this way, only the stubs eight to ten inches long remaining. Where infestations are heavy it is not uncommon to find the dead and dying canes scattered about the ground in large

numbers or leaning against other canes for support. Varieties producing strong, thick vigorous canes even though attacked by borers may continue to grow and bear a good crop of berries. This is particularly true in the case of blackberries and some varieties of raspberries.

cords the adults lived a maximum of 36 days and they were found in the field until late in August. The beetles feed for several days before oviposition begins. The female deposits her pearly-white spheroidal egg on the side of the cane and cements it in place. She then ejects a viscous material

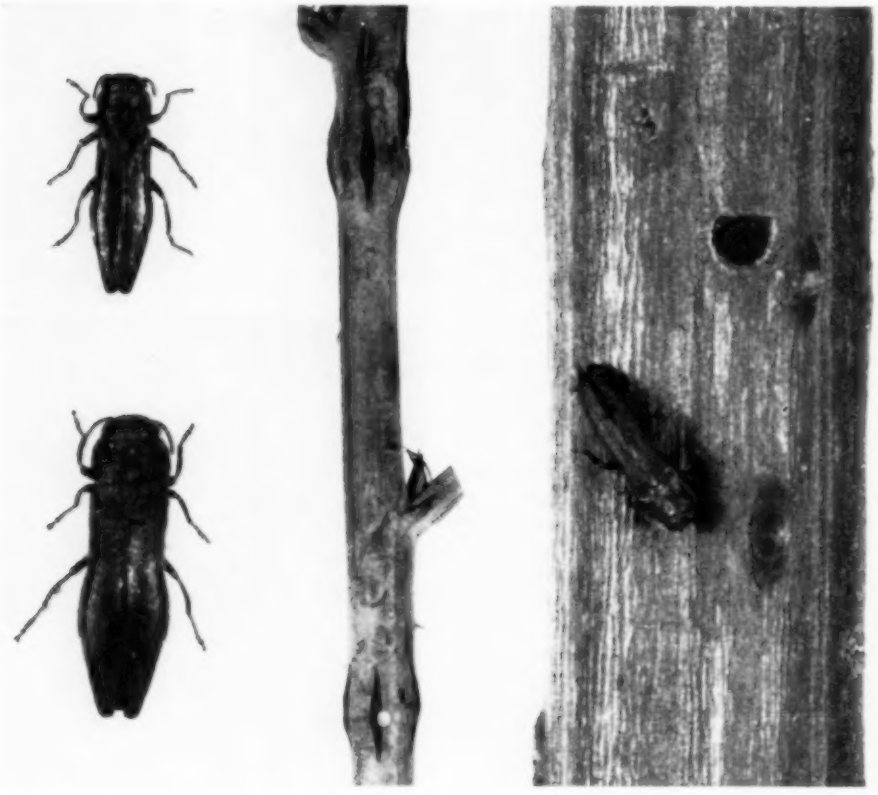


FIG. 3.—Left:—*Agrilus rubicola*, male and female ×6. Center:—Raspberry cane showing swellings caused by larvae. Hatched egg appears on lower swelling. Right:—Section of cane showing exit hole and newly transformed beetle.

SEASONAL HISTORY AND HABITS.—The graph (Fig. 4), shows air temperatures and phenological data for part of the 1938 season. The stages of plant development indicated are for Newburgh and similar varieties. It will be noted here that the adults began to emerge during the last week in May, by which time most of the blossom buds had been formed. New beetles continued to appear until the latter part of July, the emergence coinciding with the period of fruit formation and harvesting. By the middle of June, it will be observed, about half of these insects had emerged. As determined by cage re-

from the ovipositor and, using the tip of the abdomen as a trowel, spreads this substance smoothly over the surface of the egg. Several minutes are required for this operation which, when completed, transforms the egg to a lemon-colored, scale-like object (Fig. 2). The color after a day or so fades to grayish or white. The external measurements are as follows: length about 1.4 mm., width 0.9 mm., and thickness about 0.5 mm. Eggs of some females of *Agrilus ruficollis* may be slightly larger and occasionally are left naked or very poorly protected. *A. rubicola* is usually more thorough in the process of oviposi-

tion, seldom leaving an egg until it has been well covered. Confined females of both species frequently deposited more eggs on both the glass and wood of the cages than on the canes provided for that purpose. Oviposition may continue until late in July and as determined by cage studies the eggs hatch in 4 to 24 days depending on the prevailing temperatures. The larva in escaping from the egg gnaws through the side that is in contact with the bark and burrows directly into the cambium, beginning its mine just under the surface and proceeding around the cane several times in a close spiral. The tunnel at first is very small and is confined to the cambium but gradually extends deeper and is continued in the hard wood. It is in this region that the swelling or gall (Fig. 3), so well known to raspberry growers, is formed. The size of the swelling may vary in length from .25 inch to 3 inches depending somewhat on the size and vigor of the cane, and also whether or not more than one larva is involved. The galls may occur on the cane at distances from the ground ranging from an inch to 4 feet, average 20 inches. As many as eight swellings have been found on a single cane. Longitudinal cracks commonly form over the surface of the gall giving it a rough appearance. This is the weakest portion of the cane and the region at which breakage always occurs. The burrow beyond the swelling takes the form of a gradually elongating spiral extending toward the distal end of the cane where it is continued in the pith. The larva winters at the end of this tunnel and the following spring forms the pupal chamber in which it transforms to the adult. The pupal period covers from 20 to 39 days, the mature beetle escaping through an elliptical hole made in the side of the cane. The larval tunnel usually extends upwards but occasionally larvae were observed burrowing toward the base of the cane. Some of the longer tunnels measured as much as 16 inches along the cane from the point of entrance of the newly hatched larva to the emergence hole.

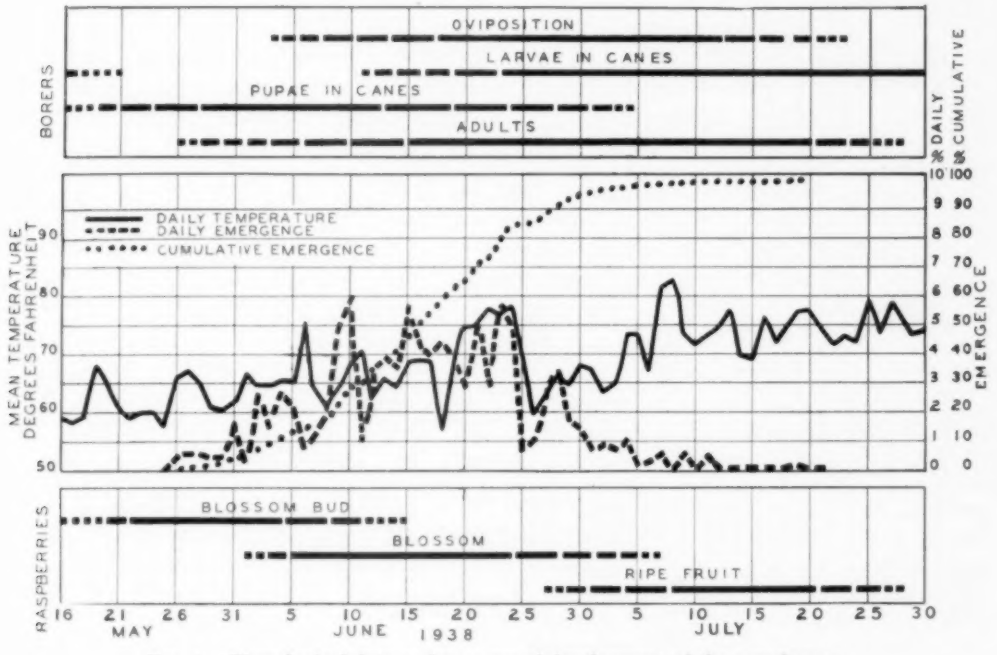


FIG. 4.—Phenological data and progress of development of the cane-borers.

CONTROL MEASURES.—One of the earliest and until recently the only recommended control for the red-necked cane-borer was the removal and destruction of infested canes. If a grower can do this while he is taking dead wood out of the planting or during his pruning operations, some good will undoubtedly result. However, experience has shown that this work

Table 1.—Summary of experiments for the control of raspberry cane-borers.

MATERIALS PER 100 GALLONS	DATES APPLIED	CANES EXAMINED	PER CENT INFESTATION	PER CENT CONTROL
	1938 Season (Sprays)			
Lead arsenate 5 lbs. Skimmilk powder 1 lb.	June 6 June 11	2641	0.15	98.43
Lead arsenate 5 lbs. Skimmilk powder 1 lb.	June 11	408	0.49	94.87
Lead arsenate 5 lbs. Goulac 4 ozs.	June 6	612	1.14	88.08
Check		544	9.56	—
	1939 Season (Sprays)			
Lead arsenate 4 lbs. Skimmilk powder ½ lb.	June 8	2802	0.50	93.49
*Ground derris root 5 lbs. Skimmilk powder ½ lb.	June 20			
Lead arsenate 4 lbs. Skimmilk powder ½ lb.	June 8	1277	1.10	85.68
Ground derris root 5 lbs. Skimmilk powder ½ lb.	June 8 June 20	1252	0.40	94.79
Kalo (sodium fluoaluminate) 5 lbs. Skimmilk powder ½ lb.	June 9	538	0.93	92.52†
Ground derris root 5 lbs. Skimmilk powder ½ lb.	June 21			
Check		1003	7.68	
	1940 Season (Sprays)			
Lead arsenate 5 lbs. Skimmilk powder ½ lb.	June 6	911	6.43	82.24
Ground derris root 5 lbs. Skimmilk powder ½ lb.	June 26			
Ground derris root 5 lbs. Skimmilk powder ½ lb.	June 6 June 26	717	10.99	69.64
Check		423	36.20	
	1940 Season (Dusts)			
Lead arsenate 25 lbs. Hydrated lime 75 lbs.	June 3	1092	5.71	84.23
Ground derris root 5 lbs. Talc 20 lbs.	June 22			
Lead arsenate 25 lbs. Hydrated lime 75 lbs.	June 3	1160	10.27	71.63
Ground derris root 5 lbs. Talc 20 lbs.	June 3 June 22	1183	4.41	87.82
Ground derris root 5 lbs. Talc 20 lbs.	June 3	1038	13.20	63.54
Check		423	36.20	—

* Containing 5% rotenone.
† Calculated from spring and fall counts.

must be done with extreme care and further, all possible outside sources of infestation should be eliminated if any measure of control is to be attained. During some seasons natural mortality may be relatively high among the borers especially among those of *Agrilus rubicola*. This appears to be due largely to the work of a small, hymenopterous parasite, *Tetrastichus rugglesi* Roh., specimens of which have been taken from nearly all locations in the tunnels. Some larvae were found to have died from other causes. Disease appears to destroy a considerable number since fungi have been found developing on many such larvae.

The feeding habits of the adults observed during the course of these studies naturally provided a clue to possible control measures. During 1938 and 1939 several acres of raspberries were sprayed with various materials directed against the insects while in the adult stage. In 1940 only a few spray tests were made, chiefly for the purpose of comparing these with dust applications. A power sprayer was used for the liquid treatments, while the dusts were applied by means of a hand duster. The first applications were made just before bloom and the second, two weeks or more later. One planting was sprayed a third time. It will be noted from the graph (Fig. 4) that the second application was made while many of the plants were in bloom. The results of some of these tests, particularly those of plantings in which check plats were used as a basis for determining control efficiencies, are shown in table 1. It might be well to mention here that the degree of control in most instances was higher when calculated on the basis of spring and fall counts. As an initial test two lead arsenate sprays were applied and it will be noted that the control following this schedule was very good. However, the use of arsenicals during bloom or after the fruit has formed is a very questionable procedure because of the danger to bees and also because of the possibility of objectionable residues remaining on the fruit at harvest. Further, it has been found that repeated, heavy applications of lead arsenate have at times resulted in an appreciable amount of yellowing and loss of foliage though one application appears entirely safe. For these reasons in later tests, ground derris root was substituted for lead arsenate in the second application with very satisfactory results. Cryolite used as a first treatment followed by a later application of a derris spray was found to give very good control. In some instances one early lead arsenate spray was nearly as effective as when followed by a second application. Though the spring of 1940 was unusually wet and repeated rains destroyed much of the protective spray and dust covers, both the lead and the derris dusts gave promise of satisfactory control. Experimental data not presented here indicate that both the lead arsenate and the ground derris root when used at the rate of four pounds in 100 gallons still provided good protection against the beetles, also that two derris sprays were about as effective as where a derris spray was preceded by one of lead arsenate. A single derris spray at the rate of 5 lbs. in 100 gallons applied immediately before bloom gave satisfactory control. The most promising schedule is one providing for 5 lbs. of lead arsenate and 0.5 lb. of skimmilk powder in 100 gallons of water applied just before bloom to be followed about two weeks later by a spray consisting of 5 lbs. of ground derris root and 0.5 lb. of skimmilk powder per 100 gallons of water. The foliage should be well wetted by the spray and any wild brambles growing nearby should also receive the same treatment. In the case of an excessively wet season, a third spray may be advisable.

This suggested schedule has been followed in commercial plantings during the past two seasons with satisfactory results. It appears doubtful, however, whether or not a heavy infestation can be cleared up in a single year since in one planting at least during the past season a flare up of the insect was noted where spraying had been discontinued the previous season.—3-26-41.

Sawdusts in Grasshopper Bait

A. V. Mitchener, *Professor of Entomology, The University of Manitoba, Winnipeg*

Introduction.—Many changes have been made in the poisoned baits that have been used to control grasshoppers during the past twenty-five years. Paris green was the first poison used. This was followed by white arsenic and then by sodium arsenite which is widely used at the present time. The first bait contained ground oranges and molasses which were believed to be especially attractive to the grasshoppers. These in some places were replaced by common salt and in other localities, amyl acetate was added to the bait. For several years in Manitoba, salt was the only ingredient used in the bait other than the carrier, poison and water. Since 1932 no salt has been used in the bait in Manitoba. In recent years baits containing oil have had their advocates. Bran alone was the carrier first used widely for the poisoned bait for grasshoppers. Sawdust came into use around 1920. In recent years mixed feed, shorts, beet pulp, flour, etc., have been used in various campaigns. For many years the recommendations were to use bran and sawdust in equal amounts by volume. Economy prompted the use of a larger percentage of sawdust in the prepared bait as in many localities it is possible to buy a carload containing at least 20 tons of sawdust at the mill for the price of a ton of bran. Some entomologists believed that grasshoppers ate only the bran and that the sawdust was a cheap filler which made the bran go further, while others believed that the grasshoppers ate the sawdust as well as the bran.

Problem.—If grasshoppers ate the particles of poisoned sawdust, several questions needed to be answered. Are different species of injurious grasshoppers attracted equally to any one poisoned bait? Are sawdusts from different tree sources equally useful as carriers for the poison? Why not use sawdust alone as a carrier for the poison? In order to secure some information on these points, experimental work was undertaken in 1935 in the Department of Entomology at The University of Manitoba with grasshoppers captured near Winnipeg. It was not possible to secure sufficient live grasshoppers locally to continue the work in 1936. As grasshoppers were again scarce in the vicinity of the University in 1937, arrangements were made to have them shipped by express from a point in southwestern Manitoba more than two hundred miles distant from Winnipeg.

Method.—Three species of grasshoppers, namely the clear-winged grasshopper *Camnula pellucida* (Scudd.), the two-striped grasshopper *Melanoplus bivittatus* (Say) and the lesser migratory grasshopper *Melanoplus mexicanus* (Saussure) are destructive to crops in Manitoba. In 1935 it was possible to secure specimens of the clear-winged grasshopper and the two-striped grasshopper, locally, in quantity. In 1937 we were able to secure specimens of the lesser migratory grasshopper. As it is easy to identify each species we could discard from any cage any specimen which did not belong to the particular species under investigation. Collections of grasshoppers caught or received from day to day were placed in cages having two sides made of wire screening. The cages were those used by shippers of package honeybees from the southern states and were $16'' \times 8\frac{3}{4}'' \times 4\frac{1}{4}''$. The grasshoppers had ample ventilation at all times and were fed fresh wheat or barley plants for at least 24 hours in every case before they were used in the poisoning experiments. All dead grasshoppers were removed from the cage before any lot was used. Grasshoppers which were shipped by express in containers used for shipping honeybees arrived in excellent condition. Ample green food had been placed in each cage before it was shipped.

Practically all of the sawdust available in carload lots in Manitoba comes from poplar, spruce and Jack pine. In order to secure a sample of each of these kinds of sawdust, a piece of dried wood from each species of tree was taken to a lumber yard and sawdust was made with one of the large saws. No sawdust from green wood was used in any experiment. Sawdust from each of these three samples was used both in 1935 and in 1937.

In the following tables the poison used was sodium arsenite at the rate of two pounds of As_2O_3 per one hundred pounds of carrier with water sufficient to moisten

Table 1.—Experiments with the clear-winged grasshopper *Cannula pellucida* (Scudd.).

CARRIER FOR THE POISON	NUMBER OF POISONING TRIALS	TOTAL GRASSHOPPERS USED	x	y	$100(x-y/x)$ % KILLED
Green barley plants	2	676	73	4	95
†Stock sawdust and bran, equal volumes+$CaCl_2$	4	952	76	5	93
Spruce sawdust and bran, equal volumes	2	747	76	5	93
Poplar sawdust and bran, equal volumes	5	1418	74	7	91
Jack pine sawdust and bran, equal volumes	2	718	76	17	78
†Stock sawdust and bran, equal volumes	4	805	89	25	72
Poplar sawdust	4	1170	74	25	66
Spruce sawdust	4	996	74	42	43
Jack pine sawdust	3	990	75	48	36
	30	8472			

† Tree origin of sawdust unknown.

Table 2.—Experiments with the two-striped grasshopper *Melanoplus bivittatus* (Say).

CARRIER FOR THE POISON	NUMBER OF POISONING TRIALS	TOTAL GRASSHOPPERS USED	x	y	$100(x-y/x)$ % KILLED
Green wheat plants	1	212	80	15	81
Poplar sawdust and bran, equal volumes	2	300	80	29	64
†Stock sawdust and bran, equal volumes	1	195	87	53	39
†Stock sawdust, bran, equal volumes+$CaCl_2$	1	179	87	60	31
Spruce sawdust	3	632	82	66	20
Poplar sawdust	3	610	82	67	18
Jack pine sawdust	3	521	82	79	2
	14	2649			

† Tree origin of sawdust unknown.

Table 3.—Experiments with the lesser migratory grasshopper *Melanoplus mexicanus* (Saussure).

CARRIER FOR THE POISON	NUMBER OF POISONING TRIALS	TOTAL GRASSHOPPERS USED	x	y	$100(x-y/x)$ % KILLED
Bran	8	880	88	45	49
Green wheat plants	6	621	87	50	43
Poplar sawdust and bran, equal volumes	8	1006	88	50	43
Jack pine sawdust and bran, equal volumes	8	900	88	51	42
Spruce sawdust and bran, equal volumes	8	901	88	54	39
Jack pine sawdust	7	709	90	82	9
Poplar sawdust	8	920	88	82	7
Spruce sawdust	8	1000	88	83	6
	61	6937			

the bait. Sodium arsenite from one prepared sample was used in all the poisoning trials in both 1935 and 1937. In five trials in 1935, $CaCl_2$ was used in the bait. The materials used were weighed out, or measured out accurately, and placed in one-half pint circular, covered cardboard containers in which the ingredients making up the complete bait were mixed thoroughly by shaking and in which the bait remained moist for several days. One heaping teaspoonful of the prepared bait was scattered on the bottom of the cage. The trials were all carried out under conditions which were considered favorable for grasshopper feeding. In 1937 the trials with different carriers were run concurrently on different days. In general this was true in 1935 and in addition some trials were duplicated the same day. Each lot of grasshoppers under experiment was given either fresh wheat or fresh barley

plants at the same time that the poisoned bait was given to them. They did not in any case need to eat the poisoned bait if they preferred the green food. The result of each trial was recorded in approximately 48 hours. The dead grasshoppers were removed from each cage and counted. The cage containing the live grasshoppers was then placed in a lethal chamber containing cyanogas. When these grasshoppers were dead, the cage was removed and the dead grasshoppers counted. Each day that a group of trials was undertaken, one or two check cages were run where the grasshoppers were given only green wheat or green barley plants. In the two years, 105 tests involving the use of more than 18,000 live grasshoppers were made. In 1935 practically all grasshoppers were in the nymph stage, while in 1937 they were mostly in the adult stage.

In computing the percentage of grasshoppers killed by any bait, the formula (Abbott 1925) $100[(x-y)/x]$ was used where x is the average percentage of living grasshoppers in the checks and y the average percentage of living grasshoppers in the treated cages. The result is the percentage of grasshoppers killed by the bait.

DISCUSSION.—Of the three species of grasshoppers used in this investigation, the clear-winged grasshopper was killed most readily with poisoned baits. Excellent results were obtained when the carrier was fine cut green barley plants or equal volumes of bran and sawdust, particularly when the sawdust was spruce or poplar. The effectiveness of the bait decreased when Jack pine sawdust was used. Clear-winged grasshoppers were killed to a limited extent when pure sawdust was used as a carrier for the poison. This was particularly true for poplar sawdust.

Fine cut green wheat plants were very effective as a carrier for the poison in the single trial where they were used for the two-striped grasshopper. Equal volumes of bran and poplar sawdust were less effective. Bran and stock sawdust were not satisfactory and very poor results were obtained with any sawdust alone. Jack pine sawdust was practically useless.

The trials which were most extensive with the lesser migratory grasshopper indicated that the baits used were much less effective than for the clear-winged grasshopper. Both bran and green wheat plants were unsatisfactory as carriers for the poison. Sawdust alone held very little attraction for this species of grasshopper.

CONCLUSIONS.—When compounding poisoned baits for grasshoppers it is evident that each species of grasshopper should be treated as a unit. It is possible that different species of injurious grasshoppers have tastes as distinct as those of the different species of domestic animals.

Sawdusts from different tree sources are not equally useful in grasshopper baits.

Sawdust alone should not be used as a carrier for the poison used to control any of the three species of grasshoppers used in this investigation.

Poisoned baits having the carrier composed of equal volumes of bran and sawdust or fine cut green barley plants are recommended for the control of the clear-winged grasshopper. Excellent kills were secured without the aid of any attracting chemical. Avoid Jack pine sawdust if possible.

It is possible that green wheat plants would make a valuable carrier for the poison for the two-striped grasshopper, but additional experimental work is needed to determine the usefulness of this suggestion. The few trials where the regular bait was used gave disappointing results. It is possible that some attracting substance should be added to the bait for this species.

Kills were uniformly unsatisfactory with the lesser migratory grasshopper when the carrier was bran or green wheat plants or bran and sawdusts in equal volumes. Experimental work should be undertaken to determine the value of attracting substances for this species.[1]—3-10-41.

[1] The writer wishes to acknowledge financial assistance received by the Department of Entomology from the Manitoba Department of Agriculture, Winnipeg, during the years 1935 and 1937 in connection with this project. I am particularly indebted to Mr. Willard R. Allen, Dominion Entomological Laboratory, Brandon, Manitoba, who caught and forwarded to Winnipeg by express from time to time nearly seven thousand lesser migratory grasshoppers during the summer of 1937. Mr. Allen was stationed at Lyleton, Manitoba, and it was from this point that the shipments were made.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. 18(2): 265–7.

Effect of Dormant Oil Sprays on the Eggs of *Stictocephala inermis* (Fab.), an Elm-Infesting Treehopper[1]

ABBOTT KAGAN and F. A. FENTON, *Stillwater, Oklahoma*

Experiments to determine the possibility of controlling the green clover treehopper, *Stictocephala inermis* by the use of dormant sprays on American elm, *Ulmus americana* L., and Asiatic elm, *U. pumila* L., were carried out at Stillwater, Oklahoma, during the winter of 1938–39. This insect occurred in unusual abundance the preceding summer and caused severe injury to young elms growing along a highway.

Previous work on the control of treehoppers on trees had been done by Yothers (1930, 1934), Sorenson (1928), Hutson (1934), and Harman (1938). Yothers sprayed the eggs of *Stictocephala inermis* with a 4 per cent oil emulsion or miscible oil and obtained satisfactory results. Sorenson used a dormant miscible oil of 10 per cent strength, such as is used in the control of the fruit-tree leaf-roller, on the eggs of the buffalo treehopper, *Ceresa bubalus* (Fab.), and found it to be an important measure in its control. Hutson, while working with *Glossonotus crataegi* Fitch, found 3 per cent dormant lubricating oils ineffective in controlling this insect, but a spray consisting of one gallon of summer oil emulsion plus one-half pint of nicotine sulfate in 100 gallons of spray completely controlled the nymphs. Harmon found that good control of *G. crataegi* was obtained by using a dormant lubricating oil-spray of 6 per cent strength.

METHODS AND MATERIALS.—*Dendrol* containing approximately 93 per cent oil, *Spra-mulsion* containing approximately 85 per cent oil, and lime sulfur, 33 degrees Baumé, were the spray materials tested. One group of trees was sprayed December 4, 1938, another March 3, and a third March 22, 1939. The spraying machine used was a wheelbarrow pump capable of producing 150 pounds pressure; each spray combination was tested on two American elms and two Asiatic elms. The efficiency of control was determined by peeling off the abnormal growth from over the egg pouches with a dissecting knife and examining the eggs. Live eggs were turgid, grayish white in color, and could easily be separated from the shriveled, blackish gray, completely deflated dead eggs. The effectiveness of each treatment was determined by Abbott's formula (Abbott 1925). On American elm, the number of eggs counted to determine per cent control ranged from 431 to 618 with a mean of 511.9. On Asiatic elm, the number ranged from 340 to 933 with a mean of 472.0.

The temperature ranged from 49° to 58° F. during the spraying of December 4, from 59° to 61° F. during the spraying of March 3, and from 65° to 66° F. in the March 22 spray. The relative humidity throughout all the sprayings ranged from 24 per cent to 58 per cent at all dates of spraying. The weather was fair, and the wind was moderate.

Apparently, leafing out of the trees was not impaired by the use of oil sprays as shown by leaf counts made April, 1939. The number of leaves per bud was counted on the sprayed trees and compared with the number forming per bud on the check trees.

Lime sulfur of four and five degrees Baumé was used but was ineffective and will not be discussed further.

SPRAY TREATMENT ON AMERICAN ELMS.—The control obtained on American elm was very poor on the first two dates of spraying (Table 1). The spray application

Table 1.—The effect of dormant oil sprays applied to American elm as ovicides for *Stictocephala inermis* (Fab.) at Stillwater, Oklahoma, 1938-39.

MATERIALS USED		PER CENT CONTROL			
		Dec. 4	Mar. 3	Mar. 22	Mean
	%				
Dendrol,	8	20.5	47.3	43.5	37.1
	6	—	17.0	63.1	40.1
	4	13.8	6.8	52.6	24.4
	2	16.7	13.1	26.7	18.8
Spra-mulsion,	8	3.0	19.7	50.7	24.5
	6	14.2	36.0	56.6	35.6
	4	27.1	15.5	42.0	28.2
	2	11.2	0.0	17.0	9.4

[1] Presented at the Philadelphia Meetings of the American Association of Economic Entomologists, December, 1940.

of March 22, however, caused a higher kill. Six per cent *Dendrol* led all materials tested in effectiveness, causing a mortality of 63.1 per cent. Closely following the *Dendrol* was a 6 per cent *Spra-mulsion* which caused a mortality of 56.6 per cent.

Table 2.—The effect of dormant oil sprays applied to Asiatic elm as ovicides for *Stictocephala inermis* (Fab.) at Stillwater, Oklahoma. 1938-39.

Materials Used		Per Cent Control			
		Dec. 4	Mar. 3	Mar. 22	Mean
	%				
Dendrol	8	67.5	30.1	73.1	56.9
	6	—	28.8	55.3	42.1
	4	80.3	39.7	32.7	50.9
	2	24.7	35.7	45.4	35.3
Spra-mulsion	8	60.7	64.9	68.5	64.7
	6	61.6	74.3	70.2	68.7
	4	59.1	50.7	64.6	58.1
	2	43.1	52.0	69.1	54.7

Due to the extreme variability of control obtained, comparisons of materials are of doubtful value. However, the mean control obtained in all the oil sprays of the March 22 spraying was 44.0 per cent as compared with 15.2 per cent and 19.4 per cent for the other two dates. Also the 6 and 8 per cent oil sprays gave better results, on the average, than the 4 or 2 per cent spray tests.

Spray Treatments on Asiatic Elms.—In the spray test applied December 4, 4 per cent *Dendrol* was the most efficient ovicide, giving a control of 80.3 per cent. Eight per cent *Dendrol* and 6 per cent *Spra-mulsion* follow, killing 67.5 and 61.6 per cent of the eggs respectively. The second spray test applied March 3 showed a decrease in general ovicidal efficiency although the difference was not great enough to be significant. Six per cent *Spra-mulsion* was the most efficient ovicide, giving a control of 74.3 per cent. In the last spray test, 8 per cent *Dendrol* gave the highest control, namely, 73.1 per cent, followed by 6 per cent and two per cent dilutions of *Spra-mulsion*.

The mean control obtained in all the oil sprays of the March 22 spraying was 59.9 per cent as compared with 56.7 per cent and 47.0 per cent for the other two spraying dates. The 6 and 8 per cent oil sprays gave a higher kill, on the average, than the 4 or 2 per cent oils.

Summary.—Better control was obtained on Asiatic than on American elm.

The results of the March 22 spraying on American elm were definitely superior to those obtained on the other two spraying dates. On Asiatic elm, no significant difference in kill was observed.

In the March 22 spray application on American elm, best control was obtained by six per cent oil sprays. On Asiatic elm, an average of all dates of spraying shows that a four per cent oil spray was about as effective as the more concentrated mixtures, and considering comparative costs, was the most efficient. Data on the effect of per cent of oil in the spray on control are conflicting in most instances, and more experiments should be carried out to clear up this point.

In general, the data show that dormant sprays are not satisfactory for controlling *Stictocephala inermis* on elms.—1-7-41.

Literature Cited

Abbott, W. S. 1925. A Method of Computing the Effectiveness of an Insecticide. Jour. Econ. Ent. **18**: 265–7.

Fisher, H. J., and E. M. Bailey. 1937. Conn. Agr. Expt. Sta. Bul. 398, p. 717, July.

Harman, S. W. 1938. *Glossonotus crataegi* Fitch Susceptible to Dormant Oil Sprays. Jour. Econ. Ent. **31**: 318–9.

Hutson, R. 1934. Observations on the Habits and Control of *Glossonotus crataegi* (Membracidae), on Plum and Apples. Jour. Econ. Ent. **27**: 365–7.

Sorenson, C. J. 1928. Treehopper injury in Utah Orchards. Utah Agr. Expt. Sta. Bul. **206**.

Yothers, M. A. 1930. Tree Hoppers and Their Control in the Orchards of the Pacific Northwest. U. S. Dept. of Agr. Circ. **106**.

Yothers, M. A. 1934. Biology and Control of Tree Hoppers Injurious to Fruit Trees in the Pacific Northwest. U. S. Dept. of Agr. Tech. Bull. **402**.

Seed-Borne Organisms and Plant Quarantines[1]

R. H. Porter, *Ames, Iowa*

The primary purpose of plant quarantines is to prevent the introduction into new areas of destructive plant or pathogenic organisms and of insects which attack plants used for food or other purposes. One of the ways in which insects and organisms that cause disease are disseminated is by contaminated seed. "Seed" in this paper is used to include bulbs, corms and tubers as well as seed in its strict botanical sense. It is the purpose of this paper to consider the interrelation of seed borne organisms and plant quarantines from the following angles:

1. The extent to which disease producing entities are carried by seed,
2. The relative importance of determining the pathological condition of seed moving in intra and international commerce,
3. Methods which may be employed in the detection of seed borne organisms,
4. The possibility and practicability of establishing proper facilities for the assistance of plant quarantine officials who might be required to regulate the seed commerce.

Dissemination by Seed of Disease Producing Entities.—Orton (1931) in his "Bibliography of Seed Borne Parasites" lists 124 kinds or species of plants for which 455 diseases are given, all caused by organisms that are partially or entirely seed borne. Conclusive proof of seed transmission in some cases is lacking, but the list of known cases is large. His list does not include organisms carried by bulbs, corms or tubers which, if added, would probably increase the number to over 600. Since the publication of Orton's list, other organisms have been shown to be seed borne, and additional research will probably enlarge the list.

It is well known that some of our most destructive plant pathogens are partially or entirely transmitted by seed, hence their presence in any region where the host is not indigenous is strong evidence that they were introduced by seed. It is recognized, of course, that an organism may be indigenous on another host yet find an introduced species or variety much more susceptible. Most of the smuts of our cereal crops including barley, oats, rye, wheat, millet, sorghum and rice have been disseminated by the seed to practically every part of the world in which these crops are grown. Even though we do not have complete evidence that the smut parasites were indigenous in the same region as their host plants, we may safely assume that under the conditions of world commerce for the past 300 years and especially before any quarantine regulations were established, there was unquestionably extensive dissemination inter-regionally and inter-continentally. Species of *Gibberella*, *Pleospora*, *Glomerella*, *Diplodia*, *Fusarium*, *Helminthosporium*, *Phoma*, *Septoria*, *Colletotrichum* and many other genera, as well as bacteria, have found their way to new localities by the agency of seed. The bulbs, corms or tubers of such plants as onion, lily, narcissus, tulip, gladiolus, iris, potato and sweet potato have carried viruses, bacterial and fungous parasites and nematodes to new localities. Some of the most extensive crop losses and serious human suffering have resulted from the dissemination of the agents of disease by seed. It is immaterial at the present time whether the movement has been largely to or away from any one country. The facts are that the extensive plant explorations by scientists from the United States and other countries as well as the extensive exchange of varieties and species of plants by investigators have made the possible dissemination of plant pathogens by seed a world wide problem which, if it is to be solved at all, must be attacked on more than a national basis.

To a farmer who intends to harvest a crop from a given lot of seed it is often of vital importance that he know the pathological condition of the seed before it is planted, but the importance of such knowledge is dependent on several factors which are listed and illustrated as follows:

1. *The pathogenicity of the organism and its severity on the crop in question.* Seeds carry many kinds of organisms, some highly pathogenic, some less so and others

[1] Presented by invitation, Section of Plant Quarantine and Inspection, Philadelphia, December, 1940.

normally saprophytic yet causing injury under certain environmental conditions All of the smut parasites that are seed borne are highly parasitic, and their presence in or on seed should be viewed as of importance although most of them yield to control. Such organisms as *Helminthosporium gramineum* (Rob.) Erik., *Septoria apii* (Br. and Cav.) Rostr., *Ascochyta pisi* Lib. and *Fusarium niveum* E. F. Sm. as well as many others are highly parasitic species; their presence on seed stocks could result in serious loss. On the other hand, species of Rhizopus, Aspergillus, Mucor, Penicillium and Alternaria may to all outward appearances cause injury in laboratory germination tests yet injury in the field may be of little consequence except in the case of scutellum rot of corn or injury to seedlings by facultative parasites when conditions for germination are unfavorable.

2. *The kind of environment to which the organism will be subjected in the locality where the seed is to be planted.* In certain regions where wheat is grown high humidity and moderate temperatures at blossoming time favor floral infection by loose smut, *Ustilago tritici* (Pers.) Rost. Seed from such an area might carry a high percentage of infection yet a cursory examination of the seed would give no indication that many of the normal appearing kernels carried the loose smut parasite. If such seed were planted in a region where soil temperature and moisture conditions at the time of seed germination were favorable for seedling infection, the loss in yield could reach serious proportions. On the other hand, if the conditions in the new region were unfavorable for floral infection, a crop of seed relatively free from infection with *Ustilago tritici* would be harvested and could be used with safety the next year in any region. Conversely, if seed wheat grown in a region where only traces of loose smut occur were planted in a region with conditions favorable for floral infection, the second crop from such seed could be seriously reduced by smut. The purpose of this illustration is to show that the importance of the loose smut organism in seed wheat is determined by the region in which the crop is to be grown.

Helminthosporium gramineum, causing stripe disease, may be present in barley seed without noticeably affecting the viability of the seed which if planted early in a region where the soil temperature remains at 15° C. or less for several days the loss in crop yield might be 30 per cent or more, depending upon the percentage of seed infection.

Diplodia zeae (Schw.) Lev. and *Basisporium gallarum* Moll. are commonly present on corn kernels in the corn belt yet the injury to seed germination will depend not only upon the degree of infection but upon the soil temperature during the period of germination. Furthermore, if these pathogens were introduced in seed to a new region in which high humidity and rainfall prevailed soon after pollination and early maturation, the losses from ear rots might become serious in a few years.

Fusarium wilts of cabbage, tomato, watermelon and sweet potato have frequently been introduced by seed into new localities where soil temperatures were particularly favorable for infection. The result has been permanent establishment of the causal agents in soils, and thriving industries have been nearly destroyed.

3. *The host range of the organism.* If a pathogen is specific like most of the smut fungi and can be controlled by seed disinfection, its presence on seed might not be serious because there would be little danger of injuring other kinds of crop plants. Organisms like *Helminthosporium sativum* (P.) K. and B., *Gibberella saubinetii* (Mont.) Sacc., *Bacterium campestre* (Pammel) E. F. S. and *Sclerospora graminicola* (Sacc.) Schr., which have a wide host range if introduced into a region where they were not previously present, might have a serious effect upon the agriculture of that region. The last mentioned pathogen was observed by the writer to cause as high as 40 per cent damage to the millet crop of Shantung Province in China.

4. *The distribution of the pathogen.* The fungi which cause smuts of cereals, sorghum and millet are more or less present in every region where the crops are grown, hence the presence of the fungi on seed would not be particularly serious because effective control measures are available. To the farmer, however, it would be important to know if there was danger of loss so that a seed treatment could be used.

Twenty-one years ago this summer flag smut caused by *Urocystis tritici* Koern.

was found in wheat fields near East St. Louis. This disease had long been known in Australia but had never been reported in the United States. Considerable damage was caused in 1919 and in succeeding years although today flag smut is no problem in the United States. Undoubtedly the organism was introduced on wheat seed. It is possible that if the proper inspection system including seed testing facilities had been in operation 25 years ago, flag smut would never have caused any damage to our wheat crop. The introduction of *Phytopthora infestans* (Mont.) de Bary into Ireland, where neither the potato nor the late blight organism were indigenous, is a classical example of the damage which can be caused by the introduction of a plant pathogen into a new locality where the environment is favorable for its development. It seems highly probable that *P. infestans* was introduced in potato tubers, but at that time no one knew anything about late blight or its causal agent.

5. *The relative resistance of the variety in question to the organism that is present on the seed.* Within the last few years the Iowa Agricultural Experiment Station in cooperation with the United States Department of Agriculture has released and increased the seed of three new varieties of oats, Marion, Hancock and Boone, all three of which are resistant to the attack of *Ustilago avenae* (Pers.) Jens. It would probably be unusual to find even a trace of smut spores on the seed of these varieties, and even if spores were present, they would be of no particular significance because of varietal resistance and the life history of the organism is such that no danger of subsequent spread to other varieties would exist. Furthermore, oat smut is present in all oat growing regions of the world, and it yields readily to seed treatment. *Fusarium niveum* E. F. Sm. may be present on the seeds of watermelon, which in the case of wilt resistant varieties might not be of serious consequence to the continued production of that variety in any locality. If infested seed of a wilt resistant variety were introduced into a locality where the soil was not infested with the wilt organism, the result might be such that nothing but wilt resistant varieties could subsequently be grown in that locality. On the other hand, the infested seed could be treated to kill the organism and thus prevent the dissemination of the pathogen.

6. *The possibility of control by seed disinfection.* In the preceding paragraphs several references were made to the control of smuts of cereals by seed treatment. Barley stripe, black leg of cabbage, scab and Rhizoctonia of potato, angular leaf spot of cucurbits and many other diseases can be effectively controlled by seed disinfection, hence the presence of the causal agents of such diseases on seed stocks would not be serious if the fact were known and control methods were employed. On the other hand, if the pathogens that cause bacterial blight of beans, ring rot of potatoes, Holcus bacterial-spot of sorghum, blight of egg plant as well as many viruses were found in seed stocks, control would be impossible by seed treatment. Use of such seed stocks would be questionable and dependent upon other factors already considered.

7. *The possibility of disseminating new physiologic forms of organisms in new regions.* Consideration of this factor is limited by the difficulty of applying it in practice yet it would not be impossible to determine what physiologic forms of some organisms are present on seeds. The time factor involved would be considerable and might outweigh the value of such a procedure. On the other hand, if a variety resistant to a considerable number of the most prevalent forms of an organism were being grown almost entirely in a community or region, it would be most unfortunate to introduce a new form and upset the balance already established between the host and parasite.

A final consideration that involves two or more of the factors to which reference has been made is that of introducing a new crop infected with a serious pathogen into an environment entirely new for both host and parasite. The changed conditions might so affect the balance between host and parasite as to make the production of that crop more hazardous than when grown in its original environment. In this connection it must be realized that different organizations, councils and agencies in the United States are interested in aromatic plants as a source of essential oils, in plants from which insecticides may be produced, in various kinds of plants that possess erosion control potentialities and in various ornamental

and shade plants. Should the seeds of such new kinds of plants be introduced and distributed freely in the United States without regard to the danger of importing dangerous plant parasites? Who knows but what some new serious pest may be introduced by the seed of plants closely related to our native species. May not some of our most productive crops be menaced by the agency of pathogens that gain entrance on seeds introduced for experimental purposes?

It is believed that enough illustrations and examples have been given to indicate the importance of knowing the pathological condition of many kinds of seed moving in intra or international commerce.

METHODS OF DETECTING ORGANISMS CARRIED BY SEED.—Theoretically it can be shown that the agricultural welfare of an individual or of a region may be in part dependent upon preventing the spread of serious plant pathogens by the agency of seed. On the other hand, the application of the principle to seed commerce depends upon the rapidity and accuracy with which the pathological condition of seed stocks can be determined.

Doyer (1938a, b), Porter (1938a, b) and Neergaard (1938) have recently published accounts of methods employed in the detection of organisms carried by seeds. A brief review of methods is presented here with an indication of those most dependable and efficient.

1. Washing seeds in sterile, distilled water with or without a centrifuge, followed by a microscopic examination of the water or residue for the presence of fungous spores. This method is particularly valuable for the determination of smut spores on the seeds of the cereals, millets and sorghum. Spores of *Helminthosporium*, *Alternaria*, *Macrosporium*, *Fusarium* and other genera may be observed by the same method. Davis (1935) and Rice (1939) used a haemocytometer to determine the spore load carried by seeds. The method gives no indication of spore viability, only the presence.
2. Microscopic examination of fruiting bodies on the surface of seeds and glumes. Pycnidia of *Diplodia zeae* and spores of *Basisporium gallarum* on corn, *Phoma* sp. on millet, *Phoma insidiosa* on sorghum and *Septoria apii* on celery are examples of fruiting bodies that may be detected.
3. Microscopic examination of seed lots for sclerotia of *Claviceps* spp. smut balls and nematode mummies is of value in the examination of seeds of the grasses and cereals.
4. Plating seeds in agar to determine what organisms are present. Surface sterilization is necessary before the seeds can be plated. This method is important in research but is limited in its application because of the difficulty of examining a large number of seeds. If the percentage of infection is less than five, at least 200 seeds should be examined.
5. Germinating seeds on top of moist blotters or filter papers in large petri dishes and moist chambers. Several modifications of this method may be used. Its value is that many seeds can be observed together with the types of fungous growth and their effect on the seedlings.
6. Growing seedlings in autoclaved soil or sand in the laboratory. This method has proved of value for the detection of seedling blights of corn, cereals, sorghum and peas.
7. Growing plants in greenhouse flats, pots and benches. This method is of special value when the presence of an organism or virus can be detected best or only by growing the plants to various stages of development. Yellow dwarf of onion, virus diseases of potato, loose smuts of barley and wheat, bacterial blight, mosaic and anthracnose of beans, Fusarium wilts of several crops and stem blight of peas are among the diseases that may be observed by this method.

The employment of methods 5, 6 and 7 requires a knowledge of the effect of humidity and temperature on the interaction of host and parasite. If the presence of a particular organism is suspected, it is necessary to provide the most favorable conditions for its expression and detection. If nothing is known as to what organisms may be present, it is necessary to provide more than one series of tests.

Perhaps the greatest need is for a more extensive investigation of the different kinds of organisms carried by seed stocks that are grown under different environ-

mental conditions, together with an attempt to simplify and improve our present methods of detection. Micro-chemical methods might well be investigated thoroughly. Studies are also needed to determine the symptoms on seedlings of specific organisms either alone or in combinations of two or more. A preliminary to this latter approach is to devise methods of growing aseptic seedlings in large numbers which can be inoculated with pure or mixed cultures and subsequently observed as to symptoms. Work on this problem is in progress in our laboratory. Good illustrations and descriptions are much needed as aids to analysts who are charged with the responsibility of examining seed stocks. Doyer (1938a, b) has made a beginning in this field, but much remains to be done.

We may accept without argument the thesis that the determination of the pathological condition of seed stocks is important and further, that some methods for the detection of seed borne organisms have been developed, but it must be admitted at the outset that practical facilities for examining a large number of seed lots have not been developed. The most important aspect of the problem, therefore, is whether or not a more concerted attempt should be made to provide the necessary facilities.

Inasmuch as this problem is primarily one of interest and concern to phytopathologists although in a practical way to plant quarantine officials, it would seem that the former group should take the initiative in an effort to develop methods and facilities. There are at least four needs which must be faced and met if a working program is to be developed. These needs are as follows:

1. More research to determine the extent and significance of organisms carried by seeds as well as to develop more efficient and accurate methods for their detection. Since reference to this need has already been made. it is necessary here to emphasize only that progress in this field will occur to the extent that plant pathologists throughout the United States and in other countries accept it as a worthy and productive field of research.
2. Trained personnel for the specific task of conducting research and of actually undertaking in a comprehensive way the examination of seed stocks for pathogenic organisms. It may well be that in the next 20 years a number of positions for well trained plant pathologists may develop in this field if practical methods for the detection of seed borne organisms are evolved. The success of this venture will be determined by the support and guidance that is given by those in responsible positions of leadership and influence.
3. Establishment of laboratories for the pathological examination of seed stocks moving in international and in interstate commerce. Obviously the United States Department of Agriculture should assume the major responsibility of providing facilities for the examination of seed stocks imported into the United States. Either the organization responsible for the inspection of seed stocks intended for entry or the plant quarantine office or the two agencies working together should assume the the responsibility for thoroughly inspecting and testing such seed stocks.

   Seed stocks moving in interstate commerce could be tested by a pathological laboratory in the destination state, but such a laboratory should be a part of or closely associated with the State Agricultural Experiment Station. In some cases the State Seed Laboratory ought logically to be the center for such inspection and investigation, but increased financial support and more trained personnel would be a necessary prerequisite. Few state seed laboratories are equipped at present to assume any such responsibility, and the same is true of the federal and federal-state seed laboratories.
4. Development of intra and international cooperation among those officials who are charged with the inspection and laboratory examination of seed stocks before and after shipment. Seed stocks originating in one country could be examined by competent officials in that country before a bill of lading is granted. At the same time a representative sample could be sent to the official agency in the destination country together with information concerning the

quality of the seed in question. In many cases the test for pathogens could be completed before the shipment arrived but following arrival an additional sample should be obtained and tested. A similar arrangement could be effected between the states or provinces of a given country. Such cooperation could be of great value in facilitating the free flow of trade and if properly and efficiently organized work to the mutual advantage of all agencies concerned.

At the present time we are only in the early exploratory stages of this problem of determining the pathological condition of seed stocks. Progress will necessarily be slow, and any attempt at control of the shipment of seed stocks from the pathological standpoint should be undertaken with great caution. We should not attempt such control until we are certain of its desirability and practicability. The possibility of differences of opinion and interpretation of results is equal to or greater than our present lack of uniformity in the determination of the purity and viability of seeds.—3-8-41.

LITERATURE CITED

Davis, G. N. 1935. Laboratory Detection of Smut in Oats. Proc. Assoc. Off. Seed Anal. **93.**

Doyer, L. C. 1938a. Leitfaden zur Untersuchung des Saatgutes auf seinen Gesundheitzustand. Int. Ver. Samen Kontrolle, Wageningen.

Doyer, L. C. 1938b. Manual for the Detection of Seed Borne Diseases. H. Veenman. anz. Wageningen.

Neergaard, Paul. 1938. Seed Borne Fungous Diseases of Horticultural Plants. Proc. Int. Seed Testing Assoc. **12**(1): 47–71.

Orton, C. R. 1931. Seed Borne Parasites. West Va. Agr. Expt. Sta. Bul. **245.**

Porter, R. H. 1938a. Indexing Farmers' Seed Lots for Seed Borne Organisms and Response to Seed Disinfectants. Iowa Agr. Expt. Sta. Res. Bul. **238.**

Porter, R. H. 1938b. Detection and Classification of Seed Borne Organisms, Their Effect on Germination and their Control by Seed Disinfection in Laboratory and Field. Proc. Assoc. Off. Seed Anal. 195–213.

Rice, William N. 1939. The Hemocytometer method for Detecting Fungous Spore Load carried by Wheat Seeds. Proc. Assoc. Off. Seed Anal. 124–7.

Dutch Elm Disease Fungus Prevalent in Bark Beetle Infested Elm Wood[1]

W. HOWARD RANKIN, K. G. PARKER and DONALD L. COLLINS

The probability that *Ceratostomella ulmi* (Schwarz) Buisman occurs frequently as a saprophyte in dead elm wood was suspected from the work reported by Collins *et al.* (1940). The authors report the following percentages of beetles carrying the fungus when they arrived at trap log stations after flight from unknown source material: in 1935 in the Bronx, New York City, 15 per cent of 411 beetles; in 1936 in a combined collection from several stations, 7.6 per cent of 688 beetles; in 1937 in Westchester County, 2.9 per cent of 3,618 beetles; in 1938 in Westchester County, 0.9 per cent of 225 beetles; and in 1939 in Dutchess County, where diseased elms had been found for the first time only a few months previously, 5.7 per cent of 122 beetles gave positive cultures.

Other experiments showed that when freshly cut elm wood, free from previous Ceratostomella infection, was subjected to beetle attack in the field it frequently became a source from which the next generation of adult bark beetles emerged carrying the fungus. At one station in the Bronx in 1936 it was shown that 27.4 per cent of the entering beetles carried the fungus into the egg-laying tunnels, while 62.5 per cent of the adults emerging from this same material carried the fungus. Later in 1937 and 1938, in the case of three lots of material in Westchester County, several hundred entering adults as well as the emerging adults of the new

[1] Presented at the Section of Plant Quarantine and Inspection, Philadelphia, December, 1940.

generation were cultured. In these lots the following build-up was shown in the percentages of beetles carrying the fungus: entering beetles 5.59 per cent and emerging beetles 13.23 per cent; entering beetles 0.93 per cent and emerging beetles 62.0 per cent; entering beetles 0.88 per cent and emerging beetles 2.05 per cent.

In addition to these determined facts, it was further found that emerging adult beetles carrying the fungus could be obtained frequently from miscellaneous collections of dead elm wood. Fifteen such lots of naturally occurring and intentionally prepared cut elm wood were collected in 1939 from regions in Dutchess and Orange counties, where the average number of known diseased elms had not exceeded annually one tree in four square miles. By culturing the emerging beetles from these 15 collections it was shown that the fungus was present in eight, (53 per cent) of the samples. The percentage of emerging beetles which carried the fungus from the positive samples varied from 1.3 per cent to 38.0 per cent.

Also, of equal significance, in assessing the importance of dead elm wood as a source of spread for the fungus, were the experimental results which showed that wood cut from healthy elms could produce as high a percentage of beetles carrying the fungus as wood from an elm that was killed by the disease.

In order to determine the frequency of the occurrence of *Ceratostomella ulmi* as a saprophyte associated with *Scolytus multistriatus Marsham* in dead elm wood of all type, the special series of samples reported on here was collected during the winter 1939–40. The beetle infested samples of wood averaged 4 to 6 inches in diameter, and 18 inches long. They were collected, as nearly as was practicable, at stations about 5 miles apart throughout an area of about 3,000 square miles. In the southern part of this area, elms killed by the fungus had been occuring annually for over eight years; and in the northern part, the first discovered diseased elms had been found only a few months previously. The wood samples were placed in cages in the greenhouse. Each day a fraction of the emerged beetles were cultured, and the remainder destroyed. Of a total of 154 samples from the entire area, 59 of the samples yielded emerging beetles that carried the fungus. These positive samples came from all parts of the six counties in the sampled area. In Westchester County, where the number of diseased elms had declined in eight years from an average of 8 or 10 trees to less than one tree to the square mile, 24 per cent of the samples yielded the fungus. In the more northern counties, where diseased elms had been found only recently, and in small numbers, averaging one tree in five or ten square miles, about 50 per cent of the samples yielded the fungus.

The above results on the samples collected during the winter, and containing the overwintering larvae of *Scolytus multistriatus*, have been duplicated in a series of similar samples containing the summer larvae of *Scolytus multistriatus* and *Hylurgopinus rufipes* Eich. Of the summer series of samples collected from Westchester County, 24 per cent of those which contained *S. multistriatus* alone or both species yielded the fungus, and of those containing only *H. rufipes*, 20 per cent were positive. In Broome County, where no *S. multistriatus* has been found, 25 per cent of 16 beetle infested samples yielded *H. rufipes* adults carrying the fungus.

The samples of beetle infested wood used in these experiments represented many types of dead elm wood, and were intentionally collected at a considerable distance from the locations of elms known to have been killed by the disease. The samples included parts of standing elms partially or entirely dead, elm trees cut or wind thrown and left lying on the ground, dead or broken branches in living elms, fuelwood piles, and broken branches lying on the ground. Such material occurs continuously where elms are abundant, and is suitable for bark beetle breeding for a variable period after the tree or part of the tree dies, or is cut or broken. Over the area of about 3,000 square miles covered by the samples used in this experiment, more than 100,000 dead or dying elms were tagged during the winter of 1939–1940 for removal or pruning at over 30,000 locations, or an average of over 30 such items at 10 locations to the square mile. This figure is exclusive of such abundant items as dead elm wood found lying on the ground and in fuelwood piles. The samples used in the experiments were mostly heavily infested small sections cut from these numerous tagged items. Although no beetles carrying the fungus

were obtained from many of the samples, this was no indication that other samples from the same source of material would also have proved negative. In fact, the behavior of the samples strongly indicated that a larger number of samples would have raised the percentage of the locations at which beetles carrying the fungus were found. This belief is based upon the wide variability in the samples of the percentage of the emerging beetles that carried the fungus, indicating that the fungus often was present only in certain colonies or parts of colonies.

Orange County, one of the six counties in the area covered by the samples, serves as a good example of the relation between the number of possible dead elm sources of spread and the number of infected living elms found dying of the disease. Diseased elms were first found in the southeastern part of Orange County in 1935. Successive zones of territory to the north and west in this county have been placed under the eradication program each year, as diseased elms were discovered beyond the zones of the previous years. During the summer of 1939 this county had the most accurate scouting to locate diseased elms that has been provided at any time. In the third zone of 140 square miles, brought under the full eradication program in the winter of 1938–39, an average of about one diseased elm (actually 1.1) in five square miles was found in 1939. During the following winter of 1939–40, there was found in this zone an average of 11 locations or 20 items of potential, or actually infested beetle material to the square mile. This was 50 times as many places, and 91 times as many items suitable for or actually breeding beetles as there were diseased elms found the previous summer. Thirty-six per cent of the samples taken from infested beetle material in this zone yielded beetles carrying the fungus. The fourth zone of 161 square miles was not included in the full eradication program until the winter of 1939–40 when the samples were collected. In this zone there was found in 1939 an average of about one diseased elm (actually 0.88) in ten square miles. During the following winter (1939–40) there was found in this fourth zone an average of 19 locations or 44 items of potential, or already infested beetle material to the square miles. This was 217 times as many places, and 506 times as many items suitable for, or actually breeding beetles as there were diseased elms found the previous summer. Twenty-seven per cent of the samples taken from the infested beetle material in this zone yielded beetles carrying the fungus. Taking the county as a whole, the number of diseased elms found has never exceeded an annual average of one diseased elm in 5 square miles, although potential or infested beetle material has been found each year at over 50 times that many locations.

Several conclusions of a general nature seem to be justified by the above results, which show that *Ceratostomella ulmi* is adapted to a saprophytic life dependent on the larval and adult activities of the bark beetles. Some of the conclusions which seem to be credible follow:

1. The saprophytic existence of the fungus is neither a newly acquired habit, nor a temporary one dependent for its continuation on the parasitic phase, since the presence of elms killed by the fungus is not required to replenish the supply of fungus-carrying beetles in a locality.

2. Since the percentage of samples containing beetles carrying the fungus was as large at the margin of advance of the disease into new territory, as it was for regions where the disease has existed for several years, it is logical to conclude that the fungus is advancing into new territory in its saprophytic stage. The appearance of elms killed by the fungus seems to be the result of its having attained a sufficient build-up in beetle infested wood to furnish the volume of chances that are required to cause infection of living elms.

3. The rate of lethal infection of living elms is very low when compared with the number of sources of spread, the number of beetles that carry the fungus when they emerge from these sources, and the number of actual inoculation points which the adult bark beetles make living elms.

4. Spread of the fungus to increasing numbers of living elms, due solely to the parasitic activities of the fungus, thus bringing about an epiphytotic build-up that would kill off the species, is no longer a justified expectation. Conversely, from experience with the disease, intensified local outbreaks have been found to be definitely connected with beetle material caused by factors other than the parasitic activities of the fungus.

5. The annual incidence of elms killed by the Dutch elm disease is dependent largely upon a low rate of effective infection originating from the current volume of bark beetle breeding material that is produced by the combination of all causes that lead to the death of elm trees, or wood.

The research reported here in summary form will be more adequately treated elsewhere. The present purpose is to emphasize the importance of a better understanding of sources of spread and conditions requisite for successful infection. Such facts are essential for determining the field procedure best adapted to reduce the incidence of the disease.—3-8-41.

LITERATURE CITED

Collins, Donald L., M. G. Parker and Henry Dietrich. 1940. Uninfested elm wood as a source of the bark beetle (*Scolytus multistriatus* Marsham) carrying the Dutch elm disease pathogen. Cornell Agr. Expt. Sta. Bul. 740.

Instability of Resistance to Aphids in Some Strains of Alfalfa

H. R. ALBRECHT,[1] *Alabama Agricultural Experiment Station, and* T. R. CHAMBERLAIN *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[2]

Blanchard & Dudley (1934) have reported that occasional alfalfa plants are resistant to the pea aphid, *Macrosiphum pisi* Kalt. They found this resistance manifest to such an extent that aphids confined on resistant plants soon ceased to reproduce and thus could not be permanently colonized. Dudley's work was done in the greenhouse, where the resistant character appeared to be stable.

Apparently if a commercial variety of alfalfa with stable resistance can be developed, its growth would be advantageous, not only where the pea aphid is intermittently destructive to alfalfa but also where this perennial serves as an overwintering host of the aphid and furnishes the initial populations on annual and other legumes. Furthermore, it seems unlikely that such an alfalfa, with no or uniformly low aphid populations, would serve to any great extent as a host for aphid-borne plant viruses, which might be carried to other crops.

With these possibilities in mind the writers obtained cuttings from two resistant Grimm plants from which Dudley had obtained his resistant stocks and crossed them with commercial varieties of alfalfa to determine whether the resistant character could be transmitted by hybridization.

PROCEDURE.—Two resistant Grimm plants, designated as AR1 and AR2 were used in the crossing. AR_21 was produced from a cutting of AR1. AR1 and AR2 were crossed with two plants of commercial varieties, one a twice-inbred susceptible Grimm and the other a once-inbred susceptible Ladak. Seed was obtained from each parent by selfing. The F_1 plants were not tested for aphid resistance but were selfed in the greenhouse the following winter. The F_2 seeds, as well as those obtained from the parent plants, were planted in the greenhouse in February 1936. Five hybrid families, counting sister families, are considered here, but others were represented in the plantings. Data could not be obtained from these latter families, which were planted in another greenhouse, since the introduced aphids soon became infected with a fungous disease to such an extent that populations could not be built up even on the non-resistant plants used as controls.

The seedling plants were infested by scattering aphids over the benches in which they were grown. To obtain a maximum infestation, other aphids were scattered over the benches at various times after the initial infestation. It is believed that sufficient numbers of aphids were placed on the plants to minimize the possibility that lack of infestation on individual plants could be due to chance rather than actual resistance. Also it was hoped that by the use of this method, after several years of repeated infestation of all plants and selection of the most aphid-resistant ones, a fair number of plants, in which the resistance appeared very high, stable, and transmittable, could be obtained. After the plants were infested,

[1] In the Department of Genetics of the University of Wisconsin when the studies were made.

[2] The authors express their appreciation to F. R. Jones for interest and counsel in the course of this work, to Lee Seaton for assistance in colonizing and counting the aphids, and to J. E. Dudley for furnishing seed and cuttings.

counts of aphids were made at intervals on each plant until the number became so great that counting was impracticable. A few plants, chiefly the most resistant ones, were caged with the aphids then present upon them.

No satisfactory procedure was devised whereby the resistance of individual plants to aphid infestation could be measured by numerical data. Counts of aphids on uncaged plants became less significant with the increase of time after the original infestation. The plants not tions on resistant plants. Since the average number of aphids per plant in all the families is based upon the counts of all aphids on all plants, whether these aphids were migrating or on individual nonresistant plants, these averages are too high to represent the true conditions on the large number of highly resistant plants in the resistant families.

Seed of the plant families to be tested were planted in flats in the greenhouse in 1936. When the seedlings were 3 weeks old they were transplanted to benches and

Table 1.—Reaction of aphids of inbred and F_2-hybrid progenies of parent alfalfa plants tested in the greenhouse during the spring of 1936.

Inbred or Hybrid with Family No.	Number of Plants	Average Number of Aphids per Plan		Percentage of Plants Free from Aphids				Percentage of Plants Killed		
		Mar. 16	Mar.[1] 19	Mar. 16	Mar. 19	Mar. 28–29	Apr. 13–14	Apr. 5–6	Apr. 13–14	Apr. 29
Resistant Grimm										
AR1	50	5.2	11.9	24.	12.	2.	4.0	18.7	34.0	36.0
$AR_1$1[2]	25	—	3.5	—	36.0	4.0	4.0	8.0	20.0	20.0
AR2	50	6.3	10.6	28.0	18.	10.	0	18.0	28.0	30.0
Susceptible Grimm 16	25	18.8	34.0	0	0	0	—	100	—	—
Susceptible Ladak 69	25	21.8	44.4	0	0		—	100	—	—
Resistant Grimm × Susceptible Grimm Sister families:										
AR3-1 (AR1×16)	75	—	17.5	—	5.3	1.3	0	20.0	34.7	36.
AR3-2 (AR1×16)	75	—	22.4	—	1.3	0	—	100.0	—	—
AR9-1 (AR2×16)	75	2.4	7.0	32.0	12.0	0	0	24.0	24.0	25.3
Resistant Grimm ×Susceptible Ladak Sister families:										
AR7-1 (AR1×69)	75	9.6	15.7	6.7	13.3	2.7	1.3	21.3	26.7	26.7
AR7-2 (AR1×69)	75	7.5	26.2	21.3	0	0	—	100	—	—

[1] By this date there were so many aphids on some of the plants that accurate counts were impossible.
[2] The selfed progeny of a cutting of AR 1.

only differed in vigor but individuals on which the aphid population increased rapidly were retarded in growth and soon became incapable of supporting as large a population as those upon which the increase had proceeded more slowly.

For the purpose of comparing the aphid resistance of individual plants or families of plants, however, it was not considered necessary to cage each plant and infest it independently, even if time and space had been available. Since the seedlings used the first year were readily killed by aphids when present in large numbers, it is believed that the record of surviving plants and the time required to kill 100 per cent of the plants in those cases where all were destroyed is the best measure of relative resistance. The average numbers of aphids per plant in the different families early in the tests were of some value, but frequent colonization and the migration of aphids from heavily infested or dying plants in both resistant and nonresistant strains appeared to produce temporary popula- 3 weeks later they received the initial infestations.

Since it was impossible to continue experimental work after the first of May, all plants surviving the tests and those still untested were transplanted to the field, where they remained during the summer. Before the ground froze the following winter the roots were removed to a cold frame, where they became frozen but were available at any time during the winter.

In January 1937 all the roots in the cold frame were brought to the greenhouse and potted. The potted plants were placed on a bench, grouped according to families, and infested, the aphids being scattered over them in large numbers.

Results in 1936.—The progress of the infestations in 1936 is summarized in table 1.

The assumption that the Grimm and Ladak plants chosen for crossing with the aphid-resistant plants were completely susceptible is supported by the behavior

of the inbred progeny of these plants, all of which were killed by aphids in about 3 weeks. The selfed progenies of the two resistant parents, the first represented in table 1 by AR 1 and AR_21, which was the selfed progeny of a cutting of AR 1, and the second by AR 2, showed a high percentage of plants resistant to the aphids, but later the number of aphids, especially on nonresistant plants, increased and the number of plants free from aphids decreased. Neither of these families exhibited the high uniform degree of susceptibility so manifest in the susceptible Grimm and Ladak plants. The reactions of the resistant families AR 1 and AR 2, as indicated by the extent of infestation and the percentage of plants killed, did not appear to be significantly different.

Sister hybrid families behaved quite differently under aphid attack. AR3-2 harbored many more aphids than its sister family AR3-1, and all plants were killed early in the test. Similarly AR7-2 proved far more susceptible than its sister family AR7-1. The hybrid family AR9-1 at first appeared to be the most resistant of the hybrid families tested, but eventually about as many plants in this family were destroyed as in the families AR3-1 and AR7-1.

During the course of these tests several plants, all but one of which appeared resistant, were caged with the aphids present upon them. Aphid development on the plants is outlined in table 2.

All plants showed some resistance except a member of the family AR3-2, which previously had proved highly susceptible. With each family a temporary increase in aphids followed the caging, apparently owing to the presence of mothers at the time of caging or to the development of mothers shortly afterward. In most cases these mothers produced young for a time, but there were no permanent increases, since the young apparently did not mature to reproduce. These results were similar to those of Dudley (Blanchard & Dudley 1934) with the same stock. This decrease in aphid population on caged resistant plants strengthens the conclusion mentioned earlier that many of the aphids found on the uncaged resistant plants on the bench represented temporary colonies produced by aphids moving from heavily infested or dying nonresistant plants or by recent artificial infestation.

A rather high proportion of winged individuals seemed to be produced on the caged resistant plants. These were frequently found on the inner sides of the cages rather than on the plants, and thus are not recorded in the table. Information is too meager, however, to permit a definite statement that caging of aphids upon

Table 2.—Reaction of caged alfalfa plants to aphid infestation during the spring of 1936.

Inbred or Hybrid with Family No.	Plant No.	Number of Aphids per Plant			
		Mar. 30	Apr. 5	Apr. 13	Apr. 22
Resistant Grimm					
AR1	1	2 young, 1 winged	18	6 young, 7 winged	1
	2	2 young	17	1 winged	0
	3	3 young	9	1 winged	0
AR2	1	1 young, 4 winged	4 young, 2 winged	5	—
	2	1 young	20	0	—
	3	0[1]	46 young[2]	0	—
Resistant Grimm×Susceptible Grimm					
AR3-1	1	10	14	2 winged	0
AR3-2	1	Many	Many, plant killed	—	—
AR9-1	1	9	42	6, 2 winged	1
	2	5	20	13, 2 winged	5
	3	15	53	25	0
Resistant Grimm×Susceptible Ladak AR7-1	1	—	2, 2 winged	1 winged	0
	2	—	1	2 young	0
	3	—	42	2 winged	2

[1] Obviously an aphid or two, probably mothers, were missed in this count.
[2] Young for the most part.

resistant plants encouraged the production of winged forms.

RESULTS IN 1937.—The initial infestation in 1937 was made on February 9, when the stems were 4 to 8 inches tall. The stems were extremely slender and bore pale foliage, probably because of poor illumination. By February 15 most of the plants of the resistant family AR3-1, as well as others which previously had appeared highly resistant, had become heavily infested with aphids and these were reproducing rapidly. Since the infestation on the year-old plants proceeded altogether differently from that on the seedlings during the previous year, it was assumed that rapid growth from stored material in the roots had produced a condition which masked the resistant character.

Thereupon the aphids were destroyed by fumigation and the plants cut back and moved to a greenhouse with better illumination. The second growth was dark green and normal in appearance. The plants were then returned to the original greenhouse and reinfested with aphids on March 20. For a short time thereafter the resistant plants harbored fewer aphids than the susceptible plants used as controls, but the difference did not persist, all plants ultimately becoming equally and heavily infested. Moreover, the aphids began laying eggs in great abundance upon resistant and susceptible plants alike. This profuse egg laying may have been induced by the occasional low temperatures to which the greenhouse was subjected in order that the rapid growth of the plants might be retarded. Conditions did not change materially in April and, since frequent fumigations to control other pests and restocking with aphids became necessary, the tests were discontinued early in May.

DISCUSSION.—The fact that plants which would not support the development of aphids in their first year, or seedling stage, became capable of supporting an abundant population of aphids a year later is clear evidence that the resistance as it occurred in the plants studied is not a stable character. It is of course possible that the resistant character would be manifest under all conditions to which the plants would be normally subject in the field. These conditions must be determined experimentally before it is safe to conclude that resistance so readily demonstrated in seedlings will protect the plants in the field from aphids and especially from aphid-borne virus diseases.

Until the relation of environment to the expression of resistance to aphids is better known, it is impracticable to determine the precise manner of the inheritance of the resistant character. Furthermore, before a study of the inheritance of this resistance, or even the effect of the environment upon the expression of this resistance, can be precise, a method must be worked out for estimation of the reaction quantitatively. Since an exploration of this kind could not be undertaken by the authors, the work thus begun was discontinued.—4-11-41.

LITERATURE CITED

Blanchard, R. A., and John E. Dudley. 1934. Alfalfa plants resistant to the pea aphid. JOUR. ECON. ENT. 27(1): 202–4.

The Illinois State Natural History Survey has just issued a bulletin on "How to Collect and Preserve Insects" by H. H. Ross. Subject to the usual differences of opinion among collectors the bulletin presents much useful information. The material should be most useful to the beginner and many entomologists will find it convenient as a reference to be passed on in answering questions from the amateurs. The bulletin comprises 48 pages and includes many clear and well-chosen illustrations.

Numbers of *Heliothis armigera* (Hbn.) and Two Other Moths Captured at Light Traps

CHAS. H. MARTIN and J. S. HOUSER,[1] *Ohio Agricultural Experiment Station, Wooster*

In 1938 and 1939 experiments were conducted particularly with *Heliothis armigera* (Hbn.) at Marietta, Ohio, to learn if light traps might be a possible method of control of this pest in tomato fields. Some of the experiments were planned to compare the attractiveness of various electric lights to the moths. The results of these comparisons are given here. The 1939 records for *Cirphis unipuncta* (Haw.) and *Protoparce sexta* (John.) are also reported.

METHODS.—Ten lamps, including *Mazda* incandescent, *Mazda* mercury, and fluorescent *Mazda*, the lights of which ranged over a wide scale of brilliance, were tested. Also there were differences in spectral distribution between lights. Descriptions of the light of each lamp will be given in the tables and with the discussion of the insect data.

The lamps were placed in two types of traps. Each consisted of three main parts; a flat cone-shaped top, a hopper, and baffles. The hopper was suspended from the top by three rods. The traps differed in baffle arrangement. In 1938, three baffles were set equidistant with their edges at right angles to the lamp. The light in this open-type trap could be seen from all directions. In 1939, a semi-circular shield was extended more than halfway around the trap as a baffle. Such a baffle directed the light beam in one direction so that a triangular area was brightly lighted in front of the trap and the area back of the trap was in darkness. Figure 1 illustrates a trap with this type of baffle. The insect container has been previously described by the senior author (Martin 1939).

In 1938 the traps were operated in a field of tomatoes. In 1939 the open-type trap was used in June in a tomato field but when the traps were moved to a field of sweet corn, the vertical baffles were replaced with the shields which were used to direct each light in a different direction. During both years all traps were operated simultaneously about 75 to 85 feet apart in order to expose all lights to the same insect population.

It was characteristic of the data to find very small numbers of moths at all lights on many nights; on others the numbers would be greater at all lights. Since the data could be paired, "Student's method," which was suggested by Dr. F. M. Wadley, was used for calculating the standard error. This method eliminated the effect of difference in population activity from night to night.

GENERAL OBSERVATIONS.—There were many nights when *Heliothis armigera* did not come to the light traps. No moths came on 30 per cent of the 78 nights that the traps were operated in 1938; none came on 22 per cent of the 91 nights that they were operated in 1939. The absence of *H. armigera* in the traps did not always indicate that they were not present in the field. None were observed at the traps and none entered them from June 17 to 22, 1938, even though the moths were laying eggs on near-by tomato plants. Similar observations were made in 1939. During August 1938 the lights were located within 300 feet of a field of late sweet corn. Fifteen to twenty *H. armigera* were found in this field on three mornings when no moths had come to the traps on the previous nights.

The flight habits of *Heliothis armigera* indicated that there were no sharp differences in their response to the various lights. In both 1938 and 1939 many individuals were observed to appear out of the darkness and to fly straight to the light. Others alighted on some near-by object and remained quiet for a period before completing their flight to the light. The moths often laid eggs on the corn while loitering near the lights. This happened frequently enough that corn within 3 or 4 feet of the lights might have larval infestations several times higher than those of corn farther away.

Heliothis armigera CAPTURED IN 1938.—Five kinds of lamps, listed in table 1, were used. The traps were operated from June 17 to September 12, 1938. Records were

[1] Acknowledgements are due the following for making it possible to conduct these experiments: C. B. Rexroad, a grower at Marietta, Ohio; L. C. Porter of General Electric Company, Nela Park, Ohio; and the Marietta Electric Company of the Monongahela System. Mr. George Wene assisted with the records in 1939.

FIG. 1—The semi-circular baffle used on the traps in 1939. Also, this figure shows the flight trails of insects flying to the *H-6* lamp. The exposure was 1/25 of a second.

kept of the number of *H. armigera* caught each night at each trap. A summary of the total number of moths per month per trap is presented in table 1.

Several investigators have reported that a number of species of moths are more attracted to lights with ultraviolet in their spectra than to those without the shorter light waves. Many of these reports are based on comparisons between mercury vapor lamps and *Mazda* tungsten lamps. In the experiment reported here (table 1), the mercury vapor *H-4* and *S-4* lamps emitted lights of equal intensity and of about the same spectral quality, but the *S-4* lamp emitted, in addition, ultraviolet, mostly in the 2900–3100 ångstrom region. The difference of 0.8 moths per night between the *S-4* and *H-4* lights was not significant, the standard error being .405 with 40 degrees of freedom. Hence, we can infer that the ultraviolet

Table 1.—Numbers of *Heliothis armigera* taken per month per trap during 1938.

Month	Number Nights Moths Came to Traps	*H-4* 100-W 3400 Lumens	*S-4* 100-W 3400 Lumens	Blue Fluorescent 15-W 270 Lumens	Tungsten Mazda 100-W 1580 lumens	Tungsten Mazda 150-W 2610 lumens
June	5	6	4	4	3	—
July	15	21	26	8	0	—
Aug.	15	38*	63	12	—	11
Sept.	6	32	38	11	—	7
Average per night		2.3	3.1	0.8	0.1	0.8

* The average difference of 1.7 moths per night between the *H-4* and *S-4* traps for August was not significant, the standard error being .816 with 14 degrees of freedom.

emitted by the *S-4* lamp did not influence the number of the moths captured.

Mere inspection of table 1 shows that the brighter mercury vapor lights were, with the exception of the June totals, more attractive to *Heliothis armigera*. The average difference between the *S-4* and blue fluorescent lights was 2.3 moths, the standard error being .722 with 40 degrees of freedom. The average difference between the *H-4* and blue fluorescent lights was 1.5 moths per night, the standard error being .506.

Brightness did not always seem to be a factor in attracting the moths. Although the brighter mercury vapor lights were more attractive on the basis of averages, yet daily records showed that on 10 nights the number of moths caught at the weak 15-W blue fluorescent light equalled or exceeded the number caught at the H-4 light, and on six nights equalled or exceeded the number caught at the *S-4* light. Not more than five moths were captured on each of these nights. The 150-W *Mazda* light which approached the *H-4* and *S-4* in brightness, was no more attractive than the weaker blue fluorescent.

DESCRIPTION OF *H-6* LAMP.—In 1939 the light of an *H-6* 1000-W mercury vapor water-cooled lamp was contrasted with the lights of three other types of lamps for the number of moths caught. The spectral distribution of the light ranged from 3800 to 7600 ångstroms, with about 82 per cent of the light in the green-yellow-orange portion of the spectrum. The maximum surface brightness was one-fifth the brightness of the sun.

H-6 CONTRASTED WITH THREE 1000-W *Mazdas*.—The *H-6* light was contrasted with that of three 1000-W *Mazdas* which were put in one trap for four nights. By using three *Mazdas* a light almost as bright as that of the mercury vapor lamp but richer in the orange-red region of the spectrum was obtained (Table 2).

These meager data indicate that the light of the *Mazdas* was about as attractive to *Heliothis armigera* as that of the *H-6*. The average difference per night between the two light traps was 3.8 *H. armigera*, the standard error being 3.041 with 3 degrees of freedom.

The average difference of 81.3 *Cirphis unipuncta* per night between the *Mazdas* and the *H-6* lamps cannot be considered

Table 2.—Numbers of moths captured at the *H-6* and three 1000-W *Mazda* lamps.

Date 1939	*H-6* 1000-W 65,000 Lumens			Three 1000-W Mazdas 62,000 Lumens		
	H. armigera	*C. unipuncta*	*P. sexta*	*H. armigera*	*C. unipuncta*	*P. sexta*
Aug. 11	2	124	37	1	37	1
12	10	58	6	0	12	1
15	5	64	16	2	534	3
16	5	119	33	4	107	6
Average moths per night	5.5	91.2	23.0	1.7	172.5	2.7

Table 3.—Number moths captured at the *H-6*, *S-4*, and blue fluorescent lights.

Date 1939	*H-6* 1000-W 65,000 Lumens			*S-4* 100-W 3400 Lumens			Blue Fluorescent 2300 Lumens		
	H. armigera	*C. unipuncta*	*P. sexta*	*H. armigera*	*C. unipuncta*	*P. sexta*	*H. armigera*	*C. unipuncta*	*P. sexta*
Aug. 18	8	90	19	—	—	—	0	38	1
19	3	41	10	0	6	2	1	4	1
20	12	238	6	1	9	0	6	83	3
22	3	66	10	2	25	7	0	7	2
23	6	614	31	1	82	6	2	8	0
24	12	138	15	7	79	9	1	5	0
	Average number moths per night								
Aug. 18–24	7.3	197.8	15.1				1.6	24.1	1.1
19–24	7.2	219.4	14.4	2.2	40.2	4.8			
Aug. 21		*H-6* not		11	2197	30	1	447	0
25		operated		—	—	—	11	152	27

sharp since the *Mazdas* were definitely superior on only one night.

The *H-6* trap was, beyond reasonable doubt, more attractive to *Protoparce sexta*.

H-6 Contrasted with *S-4* and 20-W Lights.—The attractiveness of the *H-6* light to moths was compared with that of five 20-W blue fluorescent tubes assembled in a compact cluster, and, in addition, with a *S-4* light. The blue fluorescent lamps emit from 3800–7200 ångstroms, with the peak around the blue portion of the spectrum at about 4400 ångstroms. Table 3 presents the data.

The value of *t* for the data in table 3 leads us to infer that the differences between the lights were due to chance and not to brightness. The average difference between the *H-6* and *S-4* lights was 5.0 moths per night with a standard error of 3.007 and 4 degrees of freedom. The average difference between the *H-6* and blue fluorescent lights was 5.7 *Heliothis armigera* per night with a standard error of 2.887 with 5 degrees of freedom.

The flight habits of *Heliothis armigera* also indicate that it was not any more sharply attracted to the *H-6* light than to the others because individuals were ob-

Table 4.—Number of moths caught at the type *H* lamps.

Date 1939	*H-4* 100-W 3400 Lumens			*H-2* 250-W 7500 Lumens			*H-1* 400-W 16,000 Lumens		
	H. armigera	*C. unipuncta*	*P. sexta*	*H. armigera*	*C. unipuncta*	*P. sexta*	*H. armigera*	*C. unipuncta*	*P. sexta*
Aug. 29	1	0	0	0	0	4	0	0	0
30	4	0	1	2	1	2	3	0	2
31	2	0	2	1	0	1	1	0	2
Sept. 1	0	1	5	4	1	8	0	3	3
2	0	1	1	3	0	8	9	4	4
3	8	5	0	14	13	4	9	6	2
4	6	14	0	18	41	8	18	21	1
7	2	0	1	1	0	7	1	0	0
8	3	0	0	6	3	3	1	0	0
9	2	0	15	12	2	5	17	1	4
12	3	0	0	3	0	0	2	0	0
13	2	0	0	2	1	23	9	1	2
14	17	4	1	24	12	17	12	9	2
15	32	7	4	33	8	11	10	3	2
Ave. moths per night	5.8	2.3	2.1	8.7	5.8	7.2	6.5	2.7	1.7

served to loiter about the brilliant light as they did about the weaker lights.

The *H-6* light was sharply more attractive to *Cirphis unipuncta* than the *S-3* or blue fluorescent lights during competition. However, on August 21 when the *H-6* lamp was not in operation, more *C. unipuncta* came to the *S-4* light than to the *H-6* light during the entire period of its operation.

The average difference of 9.6 *Protoparce sexta* per night between the *H-6* and *S-4* lights was not significant, the standard error being 6.204 with 4 degrees of freedom. The *H-6* light is more attractive to *P. sexta* than is the blue florescent.

Other insects showed a more positive reaction to the *H-6* light than some of the moths just discussed. The bulk of the catch was composed of caddis-flies (mostly *Potomyia flava* Hagen) and leafhoppers. Figure 1 shows the flight trails of these insects and others as they flew into the lighted *H-6* trap. All the insects caught at the three traps listed in table 3 were weighed on five nights. From August 19 to 24, 110 ounces were caught at the *H-6* light, 20.5 ounces at the *S-4*, and 22 ounces at the blue fluorescent lights.

MOTHS CAPTURED AT THE *H-1*, *H-2*, AND *H-4* LAMPS.—An experiment was made with 100-W, 250-W and 400-W type *H* mercury vapor lamps. The traps were operated for a period of 14 days. The data is presented in table 4. The computations for these data have 13 degrees of freedom.

We can infer from table 4 that the response of *Heliothis armigera* to the brightness of mercury vapor lights was not affected within the range 3400 to 16,000 lumens. The standard error is 1.427 for the difference of 2.9 moths between the *H-4* and *H-2* lights, and is 2.131 for the difference of 2.2 moths between the *H-1* and *H-2* lights.

Cirphis unipuncta did not show a preference for any of the lights listed in table 4. The greatest average difference was 3.5 moths per night between the *H-4* and *H-2* lights; the standard error was 2.191.

Protoparce sexta seemed to be repelled by the brighter *H-1* light. The difference of 5.5 moths per night between the *H-1* and *H-2* lights tests significant at the 5 per cent level but not at the 1 per cent level. The standard error was 2.242. The brilliant *H-6* light attracted more *P. sexta* than did the weaker lights (Table 3); hence, the 1 per cent level probably should be used for interpreting these data. The difference of 5.1 *P. sexta* between the *H-4* and *H-2* lights was not significant, the standard error being 2.492.

Dirks (1937) found that 200-W, 500-W, and 1000-W tungsten *Mazda* lights were nearly equally attractive to the moths he studied. Carruth & Kerr (1937) arrived at similar conclusions for *Heliothis armigera* with 25-W to 75-W tungsten and mercury vapor *Mazda* lamps.

SUMMARY.—Many *Heliothis armigera* individuals loitered about the light traps and rested on near-by objects before entering the traps. The brightness of the light did not seem to influence loitering.

Heliothis armigera and *Cirphis unipuncta* did not show any sharp preference for any of a series of lights ranging in brightness from 2300 to 65,000 lumens with the exception of a 150-W tungsten *Mazda* light. More *Protoparce sexta* came to the brilliant *H-6* light than to weaker lights.

The brigther lights of *H-4* and *S-4* lamps attracted three to four times more *Heliothis armigera* than the lights of 100-W and 150-W tungsten *Mazda* lamps, and of a 15-W blue fluorescent *Mazda* lamp.

No more *Heliothis armigera* came to a light with ultraviolet rays than to one of equal intensity and of about the same spectral quality but without ultraviolet.

The brilliant *H-6* light attracted more insects in general than the *S-4* light or the light of a cluster of five 20-W blue fluorescent lamps.—2-13-41.

LITERATURE CITED

Carruth, L. A., and T. W. Kerr. 1937. Reaction of corn ear worm moth and other insects to light traps. JOUR. ECON. ENT. 30(2): 297–305.

Dirks, Chas. O. 1937. Biological studies of Maine moths by light trap methods. Maine Agr. Exp. Sta., Bul. 389.

General Electric Company. 1939. Mazda Lamps. Bul. LD-1.

Martin, Chas. H. 1939. Description of an insect container for a traplight. Bul. Brooklyn Ent. Soc. 34(5): 255–7.

Pea Aphid Control in Maryland During 1940[1,2]

L. P. Ditman, C. Graham and Ernest N. Cory

Pea aphid control experiments at the Ridgely Sub-Station in 1940 were more extensive than in preceding years. Treatments consisted of applications of the various forms of derris, cubé and nicotine, including nicotine vapor. Since the aphid infestation developed so late in the season that little reduction of pea yields resulted, the comparative values of treatments are based for the most part on reduction of aphid populations.

Method.—The principal experiment consisted of 13 treatments and one set of check plots, each replicated four times in a random block arrangement. Each plot was approximately one-twenty-third acre. Three of six plots adjacent to these were treated with nicotine dust and three were used as checks. Observations on the value of the nicotine vaporizer against pea aphid were made in a nearby block of fertilizer plots. The machine was driven across the plots so that part of each was treated and part untreated; separate yield records were taken on the treated and untreated sections of these plots.

All treatments were made May 28, and aphid counts were taken on all plots May 27, June 1, and June 6; additional counts were made on June 12 of plots used as checks and for treatment with nicotine vaporizer and with micronized derris dust. Mosaic infection was not noticeable and no records were made. Amount of rainfall, temperature and humidity, and wind velocity and grades of the canned product from several plots were recorded as usual.

Sprays were released at 600 pounds pressure through *Agicide* nozzles spaced 6 inches apart. The nicotine plus soap spray was confined by a hood over the boom and a 25-foot muslin trailer. Dusts were applied in early morning when plants were wet with dew, humidity high (80 per cent or above) and temperature rather low. Temperatures increased from about 50° F. at the time the first applications were made to nearly 70° at midday when the last application was completed. Other conditions of the experiment are recorded in table 1.

Results.—Peas were harvested on June 12, when the preponderance of the peas were of the No. 4 sieve size, and canned samples graded standard[3] or better for both 3 and 4 sieve sizes. Averages of the yields of shelled peas in pounds per acre and of aphid population records are given in table 2. Aphid populations are expressed as the number of aphids per sweep, based on the averages of ten sweeps in each plot at each sampling. The reduction in aphids per sweep four days after treatment affords the best index of the effectiveness of the treatment.

Nicotine vapor gave a significantly better kill than any other treatment. It will also be noted from the table that the nicotine-soap spray gave a good kill, that micronization (fine grinding) of derris and cubé[4] increased kill over that obtained by the regular product, and that derris dust applied when plants were wet with dew gave better results than when plants were dry.

Three plots treated with nicotine dust, prepared by adding three parts of hydrated lime to two parts of dust containing 10 per cent nicotine sulphate in ground tobacco stems (by weight), yielded an average of 1,203 pounds of shelled peas per acre, while three associated check plots yielded 1,038 pounds of shelled peas. On May 27, the average number of aphids per sweep of treated plots was 625; on June 1, four days after treatment, the average was 131, a 79 per cent reduction; on June 6, the average was 724. The average number of aphids per sweep of the three check plots was 541 on May 27, 1,466 on June 1, and 3,704 on June 6.

Yield records of the eight plots of peas in fertilizer tests which were treated with the nicotine vaporizer gave interesting results on the value of treatment on late aphid infestation and also on the indirect effect of high nitrogen fertilizer. Fumigated parts of four plots which had had

[1] Contribution No. 528, Department of Entomology, Maryland Agricultural Experiment Station, College Park, Md.

[2] Presented at the Philadelphia Meetings, American Association of Economic Entomologists. December, 1940.

[3] According to standards of the U. S. Department of Agriculture.

[4] Prepared by the Micronizing Processing Co., Moorestown, N. J.

Table 1.—Materials used, and other facts pertaining to the 1940 pea aphid control experiment.

TREATMENT	DILUTION OF SPRAY	RATE PER ACRE	SPEED OF MACHINE (MPH)	WIND VELOCITY (MPH)	TIME OF DAY APPLIED
Spray, Derris 4.2%* rotenone, talc diluent, plus sodium lauryl sulphate	4 lb. per 100 gal., ¼% SLS	150 gal.	2.3	4–7	before noon
Atomized oil plus nicotine and derris extract		6 gal.		7	noon
Spray, Micronized derris, 1.5%* rotenone, talc diluent plus sodium lauryl sulphate	6 lbs. per 100 gal., ¼% SLS	150 gal.	2.3	4–7	before noon
Spray, Derris root extract	equivalent to 4 lbs. per 100 gal., ¼% SLS	150 gal.	2.3	4–7	before noon
Spray, nicotine sulphate and laundry soap	3 pt. nicotine sulphate and 3 lb. soap per 100 gal.	150 gal.	2.3	7	noon
Spray, micronized cubé, 1.7%*, rotenone, talc diluent plus sodium lauryl sulphate	6 lbs. per 100 gal., ¼% SLS	150 gal.	2.3	4–7	before noon
Spray, *Agicide* concentrate	as recommended	150 gal.	2.3	4–7	before noon
Derris dust, 0.78%* rotenone, talc diluent, plus 1% sodium lauryl sulphate		48 lbs.	3	1–2	4:00 A.M.
Micronized derris dust, 0.5%* rotenone, talc diluent, plus 1% sodium lauryl sulphate		32 lbs.	3	1–2	4:30 A.M.
Micronized cube dust, 0.6%* rotenone, talc diluent plus 1% sodium lauryl sulphate		34 lbs.	3	1–2	5:00 A.M.
Agicide dust D-14, 1.1%* rotenone		50 lbs.	3	1–2	5:30 A.M.
Derris dust, 0.78%* rotenone, talc diluent, plus 1% sodium lauryl sulphate		54 lbs.	3	7	11:30 A.M.
Nicotine Vaporizer		3–4 lbs.		4–7	10:30 A.M.
Check		—	—	—	—

* Rotenone analysis by Maryland State Regulatory and Inspection Service.

an application of a 5-10-5 fertilizer yielded 3,213.7 pounds of peas per acre, while the untreated portions yielded an average of 2,928.9 pounds. On the plots which had received a 10-10-5 fertilizer the fumigated parts yielded 3,467.9 pounds of shelled peas per acre while the untreated portions yielded 3,112.0 pounds per acre, 88 pounds being required for a significant difference (odds 19–1).

DISCUSSION.—The spring of 1940 was favorable for the pea crop in Maryland. Cool weather prevailing during April and early May retarded the development of aphids on peas to a point where little damage was done. By the time the aphid population was building up rapidly, pea vines had already set most of their fruit. The lateness of the aphid infestation may also have been responsible for the low rate of mosaic infection. The low yield of peas in all except the fertilizer plots was the result of a severe epidemic of a disease known as root rot.

In general, results of 1940 confirm those obtained in past years with derris and cubé dusts and sprays. Results with nicotine indicate that it is highly effective

Table 2.—Yield and aphid population records for the various treatments given in table 1.

TREATMENT	YIELD	APHIDS PER SWEEP MAY 27	APHIDS PER SWEEP JUNE 1	PER CENT REDUCTION JUNE 1	APHIDS PER SWEEP JUNE 6
Derris spray	1441 ± 61[1]	317	88 ± 23	71 ± 6.8	123 ± 26
Oil-nicotine-derris extract	1143 ± 52	316	65 ± 18	79 ± 6.2	177 ± 43
Micronized derris spray	1203 ± 44	327	37 ± 7	89 ± 1.4	77 ± 6
Derris extract spray	1276 ± 69	354	59 ± 7	83 ± 1.3	121 ± 30
Nicotine soap spray	1184 ± 71	325	28 ± 8	92 ± 2.4	76 ± 25
Micronized cubé spray	1365 ± 95	379	81 ± 5	78 ± 3.3	131 ± 24
Agicide concentrate spray	1191 ± 86	342	83 ± 26	77 ± 4.9	395 ± 174
Derris dust (nigl t)	1286 ± 129	333	36 ± 3	88 ± 1.7	45 ± 10
Micronized derris dust	1435 ± 50	375	33 ± 3	89 ± 2.4	100 ± 27
Micronized cubé dust	1213 ± 83	402	75 ± 16	77 ± 7.4	238 ± 65
Agicide dust	1147 ± 54	354	107 ± 13	64 ± 11.9	472 ± 111
Derris dust (day)	1297 ± 24	394	71 ± 3	80 ± 3.5	339 ± 29
Nicotine vapor	1236 ± 50	340	6 ± 2	98 ± 1.6	25 ± 4
Check	1135 ± 87	398	898 ± 128		2843 ± 974

[1] Standard error.

against pea aphid in dust, spray, or vapor form if properly applied in sufficient amount.

SUMMARY.—Results of the 1940 pea aphid experiments indicate:

1. Derris, either in dust or in spray, is superior to cubé for control of pea aphid.

2. Derris dusts are superior to derris sprays when applied under proper conditions.

3. Moisture on the plants at time of application of derris dusts is more important to the success of the treatment than high temperature at the time of application.

4. Micronization (fine grinding) increases the effectiveness of either cubé or derris.

5. Nicotine spray appears highly effective against pea aphid when properly applied.

6. The nicotine vaporizer gave the highest kill of all of the treatments used. —3-28-40.

Toxicities of Bordeaux Mixture, Pyrethrum and Derris, to Potato Leafhoppers[1]

THOMAS C. WATKINS, *Cornell University, Ithaca, New York*

Among the insecticides most commonly used in research on potato spray schedules in New York are bordeaux mixture, ground pyrethrum flowers, and ground derris root. While the last named is not generally considered to be of value in reducing high populations of the potato leafhopper, *Empoasca fabae* Harris, both bordeaux mixture and ground pyrethrum flowers are used for this purpose. The investigations herein described were conducted to determine the toxicities of these three materials by contact action under laboratory conditions and to obtain direct comparisons of these toxicities at strengths used in the field. It is not to be supposed, however, that results obtained are to be considered in themselves as adequate in the prediction of results to be obtained in the use of these materials under field conditions. Such is notably the case with bordeaux mixture which DeLong (1929) and Delong *et al.* (1930) have shown to exert an indirect effect through absorption of copper by the sprayed plant and its consequent ingestion by leafhoppers when feeding. DeLong (1929) also showed that the effect of pyrethrum on potato leafhoppers was a direct one in that individuals present on plants at the time of treatment were killed but that those hatching after treatment were unaffected. Later a comparison of the effects of pyrethrum and derris was presented by Allen (1936) who found kerosene steepates of pyrethrum

[1] The author gratefully acknowledges the advice and many valuable suggestions of Dr. Roy Hansberry, Toxicologist in the Department of Entomology at Cornell University.

several times more toxic to potato leafhoppers than those of derris.

The writer first attempted a test method involving the cooling of insects to the point of inactivity just prior to their being placed in open petri dishes to be passed under a precision sprayer. In 79 groups, totalling approximately 2,000 insects treated in this manner, wide variations in results were encountered between replicate groups handled as far as possible under identical conditions. As this was true among water-sprayed groups, as well as among those sprayed with insecticides, several groups were cooled and then placed under observation without being sprayed. Considerable variation in survival was still encountered so this method of testing was abandoned in favor of direct immersion of the active forms wherein only an occasional check insect died.

In testing contact insecticides under laboratory conditions a number of investigators have chosen a dipping or immersing method, with various modifications, wherein insects to be tested are confined in cages, if in active stages, and submerged in insecticides for given lengths of time. Fryer *et al.* (1923) followed such a procedure in testing the insecticidal properties of derris against larvae, Shepard & Richardson (1931) in testing the action of nicotine on aphids, Fleming & Baker (1934) in testing various materials against Japanese beetles, and Kearns & Martin (1936) and Steer (1938) in testing various ovicides. The work of Craufurd-Benson (1938) involved a very careful study of the immersion of adults of *Ahasverus advena* Waltl. with critical analyses and evaluations of the several factors such as age of insects, nutritional status of insects, temperature, humidity, etc., which might influence results.

MATERIALS.—Pyrethrum used in the tests herein described was *Powco Brand High Test Insect Powder*[2] containing 0.92 per cent total pyrethrins, and the derris was *Powco Brand Derris Powder*[2] containing 5.8 per cent rotenone and 15.3 per cent total ethyl ether extractive. Pentahydrated copper sulphate and calcium hydroxide, employed in preparing bordeaux mixture, were always used in a ratio of 2:1 respectively. Desired amounts of pyrethrum or derris were carefully weighed and placed in 100 cc. of distilled water in a glass cylinder of 150 cc. capacity, shaken vigorously before the start of a series of tests, and shaken again before each group of leafhoppers was immersed. In preparing the bordeaux mixture the copper sulphate and calcium hydroxide were dissolved separately in 50 cc. of distilled water and then the two solutions were poured into one cylinder and shaken thoroughly.

EXPERIMENTAL PROCEDURE.—At the suggestion of Dr. F. W. Poos of the U.S. Department of Agriculture, stock cultures of potato leafhoppers were maintained on

FIG. 1.—Ventilated celluloid cages used in rearing stock cultures of leafhoppers on groups of broad bean plants.

broad bean plants, *Vicia faba* L., over which were placed ventilated celluloid cages of the type shown in figure 1. Transfers of adults from such cultures were made every fourth day to uninfested plants from which insects were removed on the following day for immersion tests. Thus all insects treated were adults between one and five days old. The number treated in each group was usually about 25, never less than 18 nor more than 42, but was greater than 30 in 55 groups (out of 159 tested) which happened to be scheduled for treatment on days when the cultures of insects contained larger numbers than was normally the case. Figure 2 shows the straight-tube aspirator with interchangeable glass barrels of 2 cm. outside diameter used in handling the insects. The desired number of insects to be immersed were sucked into a barrel whose ends were then covered with cheesecloth held in place by rubber bands. Loose edges of cheesecloth afforded a means of holding the tube while it was being immersed and moved up and down for 30 seconds in the

[2] John Powell & Co., New York City.

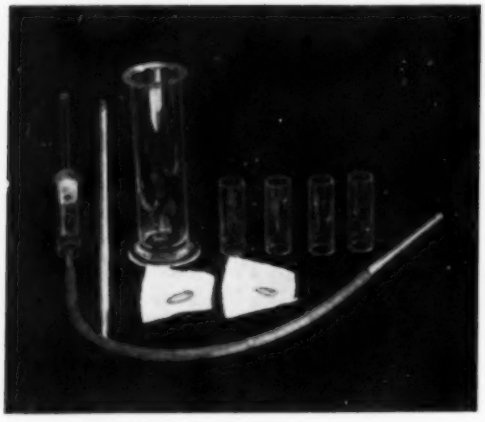


FIG. 2.—Apparatus used in transferring and immersing leafhoppers.

glass cylinder of test material the temperature of which had been previously recorded. After such treatment one end of the tube was uncovered and the treated insects were spilled into a 3 by 6 inch celluloid sleeve-cage which had been slipped over the top few inches of an uninfested broad bean plant. Care was taken to see that no insects were stuck against the sides of the cage. Usually four such observation cages were fastened on four plants grown in the same pot, as illustrated in figure 3, one cage being used to confine insects treated with each of the four materials tested, including distilled water. All insecticides under investigation were used on each testing date until some were discontinued because of evident lack of toxicity. Kills were recorded at the ends of 48-hour observation periods, records of maximum and minimum temperatures being taken just outside the observation cages during these periods. Treated insects were not kept under conditions of constant temperature and humidity although an effort was made to keep the temperature of the greenhouse in which the tests were run as nearly 75° F. as possible.

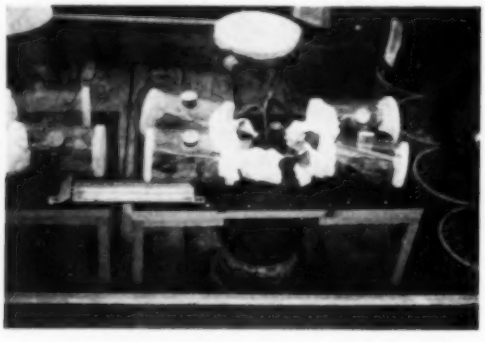


FIG. 3.—Observation cages used in confining immersed groups of leafhoppers on tips of broad bean plants.

Table 1.—Toxicities of bordeaux mixture, and aqueous suspensions of pyrethrum and derris, to adult potato leafhoppers.

INSECTICIDE	GRAMS PER 100 CUBIC CENTIMETERS	NO. INSECTS IMMERSED	NO. INSECTS KILLED	NET[1] PER CENT MORTALITY
Pyrethrum	.2604[2]	111	111	100.00
	.1302	126	117	92.81
	.0651	128	124	96.88
	.0326	139	131	94.24
	.0163	141	125	88.65
	.0082	99	75	74.28
	.0041	101	52	48.54
	.0021	97	51	49.69
	.0010	119	12	8.11
	.0005	96	6	3.61
Derris	1.6528	89	19	21.34
	.8264	80	4	3.78
	.4132[3]	85	6	5.86
	.2066	92	5	4.21
	.1033	94	14	14.89
Bordeaux[4]	3.8336	90	1	0.00
	1.9168	136	8	5.20
	.9584[5]	113	3	1.85

[1] Mortality corrected by Abbott's formula from kills of leafhoppers immersed in water on the same days on which insecticides were tested. Mean gross mortality of 828 water-immersed insects was 1.45 per cent.

[2] Equivalent to 4 pounds of 0.5 per cent flowers per 100 gallons.

[3] Equivalent to 4 pounds of 5.0 per cent rotenone dust per 100 gallons.

[4] Weight given is for copper sulphate, twice that of calcium hydroxide.

[5] Equivalent to 4-2-50 bordeaux.

RESULTS.—The per cent mortalities which occurred in the various groups of treated leafhoppers are listed in table 1 after correction by Abbott's formula (1925) for the small per cent kills obtained in water-treated checks. Of the three insecticides employed only the pyrethrum showed any appreciable toxicity as regards contact action, and since this was observed to be the case early in the series of tests the other materials were soon discarded while further trials were made on lower concentrations of pyrethrum in order to determine the dosage-mortality curve of this one material as presented in

figure 4. Work with derris and with bordeaux mixture was not discontinued, however, until each of these had been tested at concentrations twice and four times as high as those generally used in field spraying operations.

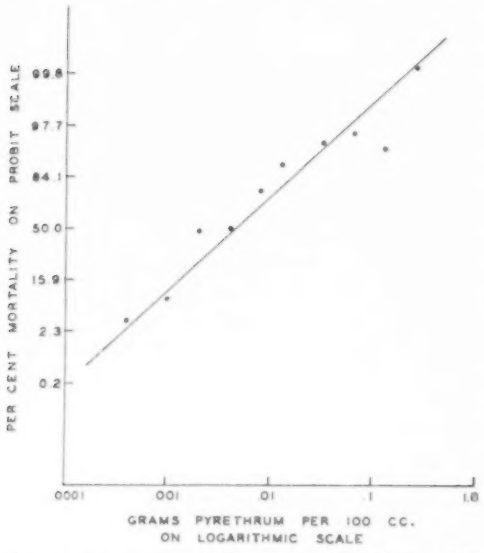


FIG. 4.—Dosage-mortality curve for 1157 adult potato leafhoppers immersed in aqueous suspensions of ground pyrethrum flowers.

The results obtained by DeLong and his co-workers were corroborated at least to the extent of concluding that pyrethrum acts upon potato leafhoppers as a contact insecticide while bordeaux mixture does not, and those of Allen were substantiated in a similar comparison between pyrethrum and derris. It is interesting to note that in the tests with pyrethrum net mortalities of higher than 90 per cent were obtained from the use of all concentrations as great as one-eighth of that generally used in the field.

SUMMARY.—A slightly modified immersing method, particularly suited to testing liquid contact insecticides against leafhoppers, is described. Application of this procedure in tests with bordeaux mixture and with aqueous suspensions of pyrethrum and derris showed only the pyrethrum to have any appreciable toxicity in contact action on adult potato leafhoppers. A dosage-mortality curve for this material is presented.—3-31-41.

LITERATURE CITED

Abbott, W. S. 1925. A method of computing the effectiveness of an insecticide. JOUR. ECON. ENT. **18:** 265–7.

Allen, T. C. 1936. Toxicity of kerosene steepates of derris and pyrethrum to some potato insects. JOUR. ECON. ENT. **29:** 742–3.

Craufurd-Benson, H. J. 1938. An improved method for testing liquid contact insecticides in the laboratory. Bul. Ent. Res. **29:** 41–56.

DeLong, D. M. 1929. The role of bordeaux mixture as a leafhopper insecticide. JOUR. ECON. ENT. **22:** 345–53.

DeLong, D. M., W. J. Reid, and M. M. Darley. 1930. The plant as a factor in the action of bordeaux mixture as an insecticide. JOUR. ECON. ENT. **23:** 383–90.

DeLong, D. M., W. J. Reid, and M. M. Darley. 1930. The toxicity of copper to the potato leafhopper. JOUR. ECON. ENT. **23:** 390–4.

Fleming, W. E., and F. E. Baker. 1934. Testing contact insecticides on the Japanese beetle, and results with some sodium and potassium soaps. Jour. Agr. Res. **49:** 29–38.

Fryer, J. C. F., R. Stenton, F. Tattersfield, and W. A. Roach. 1923. A quantitative study of the insecticidal properties of *Derris elliptica* (tuba root). Ann. Appl. Biol. **10:** 18–34.

Kearns, H. G. H., and H. Martin. 1936. Investigations on egg-killing washes. The ovicidal properties of lauryl rhodanate. Long Ashton Agr. and Hort. Res. Sta. Ann. Rept. **1935:** 49–57.

Shepard, H. H., and C. H. Richardson. 1931. A method of determining the relative toxicity of contact insecticides, with special reference to the action of nicotine against *Aphis rumicis*. JOUR. ECON. ENT. **24:** 905–14.

Steer, W. 1938. Laboratory methods for the biological testing of insecticides. I. Methods of testing ovicides. Jour. Pomol. and Hort. Sci. **15:** 338–55.

Derris and the Control of the Mexican Bean Beetle[1]

H. C. Huckett, *Long Island Vegetable Research Farm, Riverhead, N. Y.*

Rotenone-containing dusts and sprays are commonly regarded as highly satisfactory materials for control of the Mexican bean beetle.[2] Their effectiveness has been attributed to the toxic action of the active principles of the insecticide when brought in contact with or when ingested by the insect whilst feeding. It has also been claimed that they possess marked deterrent or repellent properties when sprayed on the foliage (Turner 1932) (Hamilton 1937) (Fulton & Mason 1937) (Gimingham & Tattersfield 1928). Owing to the combination of ways by which such mixtures may serve to protect bean plants it was deemed desirable that more detailed observations be made than had hitherto been recorded in order to understand properly some of the relationships existing in the field between the application of derris sprays and the resultant control. In this study chief attention has been given to observing the ways by which derris sprays may be said to function when applied for the purpose of checking immediate larval injury to the plant. Advantage was also taken of the occasion to include tests with bordeaux mixture, since no plausible reason had yet been suggested to account for satisfactory results obtained with such sprays, especially when containing derris powder.

In preliminary trials it was evident that larvae and adults, but particularly larvae, were susceptible to the ill-effects of adverse environmental conditions such as when deprived of normal moisture requirements or if exposed temporarily to unduly warm temperatures, or to the interplay of two such forces. On the other hand the insect was capable of surviving extended periods under artificial conditions provided moisture was present. It therefore seemed desirable in studies concerning the reaction of the insect to the presence of derris spray residues that special precautions be taken to satisfy the physical needs of the insect with regard to moisture and temperature conditions within the cages. This care seemed all the more important in view of the fact that in tests on the effect of rotenone-containing residues on larval activity mortality during the limited period of exposure was commonly attributed to starvation rather than desiccation. It was also evident from preliminary trials that to maintain sprayed foliage in a fresh condition for a week or so required the use of growing plants placed under well lighted conditions, such as in an open greenhouse. To help offset some of the more obvious defects in such an arrangement whitewash was sprayed over the glass of the house; blinds and tobacco cloth were used to screen the bench on which the cages were set.

The usual procedure in such tests was as follows: Larvae or adults of the first and second generations were collected in unsprayed fields during August, September and October. Insects were collected in the morning in paper cups containing foliage in quotas of 20 to 40 specimens per cup. So far as possible only medium sized larvae were selected for test purposes. Treatment followed during the afternoon. Larvae were confined for experimental purposes by means of lantern chimneys covered with cheesecloth, adults by cylindrical wire screen cages. Each cage except those without food contained two bean seedlings. Watering of plants was accomplished by means of shallow troughs. In cases where foliage was sprayed, leaves were allowed to dry before insects were introduced. So-called contact sprays were applied to larvae placed on sheets of absorbent paper, and to adults confined in wire screen tubes. The following sprays were applied: (1) calcium caseinate spreader 1.25 gm., water or bordeaux mixture (4:4:50) 500 cc., (2) standard derris powder (5 per cent rotenone) 2.5 gm., calcium caseinate 1.25 gm., water or bordeaux mixture 500 cc., (3) stabilized derris powder (4.75 per cent rotenone) 2.5 gm., calcium caseinate 1.25 gm., water or bordeaux mixture 500 cc. In addition there were two controls in each series of tests—one in which insects were provided with food and the other where food was omitted. Each test was performed intriplicate whenever treatments were applied.

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 440, April 7, 1941.

[2] *Epilachna varivestis* Muls.

During the course of these experiments it was commonly observed that in cases where untreated larvae were confined with foliage sprayed with a derris mixture very few of them remained on the plants or were seen to search the foliage for food. For the greater part of the time larvae remained on the soil. On examining cages containing derris sprayed foliage it was observed that the leaves showed signs of very little feeding and that in some such instances the leaf surface was marked with a brownish exudate apparently as a result of regurgitation. A large proportion of the larvae had been able to survive such conditions after five days' confinement. It was also noted in cages where little or no feeding had been attempted or where larvae had been left without some source of food that cannibalism had accounted for the death of some of the larvae. This phenomenon was probably due to enforced hunger under cage conditions. In the case of treatments containing bordeaux mixture it was generally observed that larvae were deterred from feeding owing to the presence of bordeaux mixture itself, but that the amount of food consumed was much less when derris powder was included in the treatment. Adults appeared to react under such conditions in much the same manner as larvae, except that they were generally found on the upper parts of wire cages and in no instance was cannibalism observed.

In each series of tests results were recorded five days after the commencement of treatment and were expressed in terms of the average percentage mortality and according to extent of foliage injury for each treatment. Doubtful cases of mortality were retained in cages furnished with fresh food for a further period of three days, after which specimens were considered dead if no movement was shown when exposed to direct sun or electric light. Larvae destroyed by cannibalism were counted as not having been killed by the effects of treatment.

In tests with larvae there was a considerable degree of difference in the average percentage mortality from treatment between the various series as carried out on several separate occasions, evidently due to various factors that were beyond the control of experimental procedure. Results in this respect tended to show that the mortality level was generally lower when the experiment was carried out under cool temperature conditions, such as commonly occur during the latter part of the season on Long Island, and generally higher when the experiment was carried out under warmer spells during the summer. However comparisons drawn between treatments in each of the several series indicated invariably a common trend in the results similar to that expressed by the average percentage mortality for each treatment in all series. When results were expressed according to degree of foliage injury by feeding the comparisons between treatments were uniformly consistent whether recorded per series or on the basis of averages for all series.

EFFECTIVENESS WHEN LARVAE OR FOLIAGE ARE SPRAYED.—In an attempt to measure the comparative effectiveness of rotenone- and copper-containing sprays when applied for contact and noncontact purposes two comparative series of treatments were made, one in which the foliage was sprayed and larvae were not sprayed, the other in which larvae were sprayed and foliage left unsprayed. These tests were made on five occasions, data from which are summarized in table 1.

The data pertaining to percentage mortality clearly indicated that larvae, as sampled, were much more susceptible to the toxic effect of rotenone sprays when the latter were applied as contact sprays than when applied to the foliage for purposes of ingestion. It was also evident from the data obtained in the control cages under starvation conditions that the majority of larvae had not died of starvation under existing conditions, and that there were small grounds for assuming that the effectiveness of rotenone-containing sprays was due to their toxic properties as stomach poisons with such larvae. That they were otherwise highly effective when applied in this manner may be concluded from the fact that foliage of plants thus treated was, if anything, more effectively protected than in the case of contact sprays.

In tests with bordeaux mixture and derris powder it was evident that in general the results compared favorably with those obtained with calcium caseinate and derris powder. Bordeaux mixture itself when sprayed on foliage seemed to give

considerable protection from excessive larval feeding. In these tests the data from treatment with a so-called stabilized form of derris powder were slightly superior to those from treatment with a standard grade of derris, but it is doubtful whether such differences were sufficiently large to be significant.

It may be concluded from these results that derris sprays were lethal when they came into contact with larvae. When derris sprays did not come into direct contact with the insects a large proportion of the larvae was capable of surviving the treatment, despite the fact that they were deterred from feeding owing to the presence of derris on the foliage.

EXTENT OF REPELLENCY.—Although it had become apparent that the effectiveness of derris sprays might be attributed largely to their so-called repellent properties, it seemed desirable that further information be gathered relative to the degree or extent of repellency in view of the large proportion of larvae that survived such treatment and owing to the fact that under field conditions fresh food would quickly be forthcoming as a result of new growth.[3] In order to ascertain whether or not the protective influence of derris spray residues on the foliage might be extended in some degree to include unsprayed plants placed immediately adjacent sprayed plants, or whether or not the larvae might be capable of detecting a difference between sprayed and unsprayed plants for feeding purposes, an experiment was planned in which much of the procedure outlined for previous tests was repeated, except that in place of contact sprays there was substituted a treatment in which one of the two plants in each pot was sprayed and the other left unsprayed. The plants were not permitted to touch each other until after the spray had dried on treated plant. These tests were made on three occasions. The data are summarized in table 2.

Table 1.—Comparative effectiveness of derris sprays when applied to larvae of *varivestis* for contact purposes or to the foliage of beans as a stomach poison as expressed in larval mortality and extent of feeding injury.

SPRAY TREATMENT AND METHOD OF APPLICATION	TOTAL LARVAE	AVERAGE PER CENT MORTALITY	NUMBER OF PLANTS			
			Degrees of Foliage Injury			
			Trace	Slight	Moderate	Severe
Water and calcium caseinate						
foliage	469	6.2			4	26
contact	446	9.7			2	28
Water, calcium caseinate and standard derris powder						
foliage	443	32.8	28	2		
contact	483	70.6	26	4		
Water, calcium caseinate and stabilized derris powder						
foliage	482	37.9	30			
contact	481	78.4	24	5	1	
Bordeaux mixture and calcium caseinate						
foliage	473	11.1	6	18	6	
contact	472	8.2		6	4	20
Bordeaux mixture, calcium caseinate, standard derris powder						
foliage	418	19.7	30			
contact	485	61.1	22	6	2	
Bordeaux mixture, calcium caseinate, stabilized derris powder						
foliage	432	29.3	30			
contact	464	65.1	25	5		
Control, fed	470	7.4			2	28
Control, starved	449	29.5				

Table 2 summarizes the data obtained from these tests. The data indicate that the protective influence of derris spray residues on the foliage is not extended to include unsprayed plants placed immediately adjacent sprayed plants, and that the larvae are not capable of detecting a difference between sprayed and unsprayed plants for feeding purposes.

[3] During the course of these experiments Fulton & Mason (1937) have claimed that the constituents of derris powder may be translocated from treated foliage to new growth on the same plant, a phenomenon that merits more detailed observation than provided for in this study.

The results from these tests tended to emphasise the nonlethal effect of derris sprays under such circumstances as well as to clearly indicate that their protective influence was limited to plants on which they occurred. It was evident also despite the intermingling of sprayed and unsprayed leaves within the same cage that larvae were capable of detecting a difference between such leaves for feeding purposes, and further in view of the extent of injury to unsprayed foliage it seems that larvae were not seriously deterred from feeding by the proximity of derris treated plants.

The results from treatments containing bordeaux mixture closely paralleled those of similar tests in the previous experiment. The protective influence of derris-bordeaux mixture sprays was confined to plants thus treated. Even after a period of five days sprayed leaves showed little injury from larval feeding. No corroborative evidence was forthcoming that might provide grounds for the disuse of sprays containing derris powder and bordeaux mixture on the score of insufficient protection. However other phases of the problem require elucidation before the full meaning of such results can be explained (Roark 1937) (Allen & Brooks 1940).

INFLUENCE OF DRY AND MOIST SOIL CONDITIONS ON LARVAL MORTALITY.—It may be deduced from the results of the foregoing experiments that derris sprays as applied were reasonably efficient in protecting bean foliage, their greatest weakness from practical considerations being apparently that they failed to kill a large percentage of larvae unless applied directly as contact sprays. It was also evident that a large proportion of larvae was able to survive without food for several days under what might be considered favorable humidity and temperature conditions. It was felt in the light of these results that it would not be superfluous to a better understanding of the relation of derris sprays to control if an attempt was made to render some accounting for the

Table 2.—Comparative effectiveness of derris spray residues when applied and when not applied to foliage immediately adjacent sprayed plants as expressed by larval mortality and extent of feeding injury.

Spray Treatment	Plant Treatment	Total Number of Larvae	Per Cent Average Mortality	Total Number of Plants	Number of Plants			
					Degrees of Foliage Injury			
					Trace	Slight	Moderate	Severe
Water and calcium caseinate	both sprayed	280	7.2	18				18
	one sprayed	243	4.1	9				9
	one unsprayed			9				9
Water, calcium caseinate, standard derris powder	both sprayed	268	19.9	18	18			
	one sprayed	234	11.8	9	9			
	one unsprayed			9				9
Water, calcium caseinate, stabilized derris powder	both sprayed	251	23.5	18	18			
	one sprayed	251	17.3	9	9			
	one unsprayed			9				9
Bordeaux mixture, calcium caseinate	both sprayed	249	5.1	18		15	3	
	one sprayed	248	4.6	9	3	5	1	
	one unsprayed			9				9
Bordeaux mixture, calcium caseinate, standard derris powder	both sprayed	243	12.7	18	18			
	one sprayed	247	11.3	9	9			
	one unsprayed			9			1	8
Bordeaux mixture, calcium caseinate, stabilized derris powder	both sprayed	246	13.3	18	18			
	one sprayed	264	14.1	9	8	1		
	one unsprayed			9			1	8
Control, fed		255	6.3	18			1	17
Control, starved		239	10.4					

probable fate of larvae in such circumstances under field conditions.

According to the literature (Marcovitch & Stanley 1930), (Sweetman & Fernald 1930), (Sweetman 1931) the activities of the insect are closely correlated with the existence of certain climatic and soil conditions. In periods of more or less drought a large number of the population may die from starvation, desiccation, or from both causes. It is conceivable therefore that larvae that are deterred from feeding or are repelled from staying on the foliage due to the presence of derris are likely to spend a greater proportion of their time on the ground searching for suitable living conditions. In such an environment during the summer season the chances of survival are seriously diminished owing to unfavorable influences inherent in such a situation. With a view to obtaining some conception concerning the possible effect of any one of such factors on conditions as they existed in these experiments it was planned to carry out tests in which the contrasting influences of moist and dry soil might be compared as reflected in larval mortality. Thus one half of each treatment was furnished with pots in which the surface soil was dry, and in the other half the soil was kept moist. Three treatments were incorporated with each set of soil conditions, namely, (1) foliage present and not sprayed, (2) no food provided, (3) foliage present and sprayed with a derris mixture. Where no food was provided a small piece of wire gauze was inserted in the cage to provide larvae an additional means of leaving the soil. To help maintain a dry condition on the soil surface and yet provide the necessary moisture for plant growth, all in the same pot, a layer of paraffin was implanted below the surface soil to interrupt capillarity. These tests were made on five occasions. The data are summarized in table 3.

From the data presented in table 3 it will be seen that a higher percentage mortality was obtained in cages provided with a dry surface soil, other things being equal. The degree of mortality was raised considerably where larvae were deprived of food, either by the presence of derris spray on the foliage or by the omission of food in the cage. Where such a condition occurred in combination with dry soil the percentage mortality again rose perceptibly. That the mortality in cages containing sprayed foliage and a dry soil was not as high as in cages containing no food and a dry soil may be mainly attributed to the alleviating influence of plant transpiration within glass cages. From these data it seems evident that dry conditions on the soil surface may have a marked bearing on the degree of larval mortality secured from treatments containing rotenone. Such hostile influences, which are commonly to be met with during the season, may in part serve to explain why rotenone-bearing insecticides are apparently so successful in protecting bean foliage from feeding injury by larvae of the Mexican bean beetle.

Table 3.—Comparative influence of moist and dry soil conditions as expressed in larval mortality.

Treatment	Soil Condition	Total Larvae	Mortality	Plants Injured	
				Slightly	Severely
Control, foliage unsprayed	moist	665	7.5		30
	dry	623	13.7		30
Control, no foliage	moist	659	32.2		
	dry	637	87.0		
Treated, foliage sprayed	moist	663	36.3	30	
	dry	677	54.8	30	

Tests with Adults.—A similar series of tests though not as extensive was made with adults of the Mexican bean beetle, the results of which were essentially similar to those obtained with larvae. Adults were readily killed when directly sprayed with derris mixture, and were successfully repelled by derris residues on bean foliage. In the latter case few of the beetles were killed, but the foliage was as free from feeding injury as in the case of contact sprays, where a large proportion of the

beetles had been killed by the treatments.

Adults, like larvae, were capable of detecting a difference between derris sprayed foliage and unsprayed foliage within the same cage for feeding purposes, with the result that leaves were practically uninjured by feeding in the former case and were severely injured in the latter.

The percentage mortality among adults was increased considerably when the surface soil was kept dry as compared to a moist condition, provided beetles were deprived of food or prevented from feeding.

SUMMARY.—Experiments were conducted under greenhouse conditions with larvae and adults of the Mexican bean beetle for the purpose of observing more closely the relation of derris sprays to Mexican bean beetle control.

Tests carried out under conditions of moisture and temperature considered favorable for the insect indicated that a large percentage of larvae and adults were capable of surviving 5 days' exposure to the presence of foliage sprayed with derris powder and that little if any feeding had taken place. Further tests indicated that the insect was capable of distinguishing sprayed and unsprayed foliage in the same cage for purposes of feeding, and that the proximity of derris on the foliage had little if any effect in retarding the insect from feeding on unsprayed foliage.

Supplementary tests confirmed the fact that derris sprays are lethal when larvae and adults are directly hit in spraying. Otherwise their effectiveness when applied as for purposes of ingestion was dependent on their repellent properties and, in the case of larvae, on desiccation as a result of unfavorable living conditions on the soil surface.

Tests with bordeaux mixture indicated that the spray residue on foliage served to reduce the amount of feeding by both larvae and adults, and when containing derris powder exerted a marked effect in protecting the foliage.—4-14-41.

LITERATURE CITED

Allen, T. C., and J. W. Brooks. 1940. The effect of alkaline dust diluents on toxicity of rotenone-bearing roots as determined by tests with houseflies. Jour. Agr. Res. **60**(12): 839–45.

Fulton, Robert A., and Horatio C. Mason. 1937. The translocation of derris constituents in bean plants. Jour. Agr. Res. **55**(12): 903–7.

Gimingham, C. T., and F. Tattersfield, 1928. Laboratory experiments with non-arsenical insecticides for biting insects. Ann. Appl. Biol. **15**(4): 649–58.

Hamilton, C. C. 1937. Tests with derris powder or cubé powder in rosin residue emulsion sprays for the control of shade tree insects. Proc. 13th Nat. Shade Tree Conference. 140–50.

Marcovitch, S., and W. W. Stanley. 1930. The climatic limitations of the Mexican bean beetle. Ann. Ent. Soc. Amer. **23**(4): 666–86.

Roark, R. C. 1937. An insect that breathes through its nose. JOUR. ECON. ENT. **30**(3): 526.

Sweetman, Harvey L. 1931. The Mexican bean beetle. Wyoming Agr. Expt. Sta. Bul. **176**: 1–23.

Sweetman, Harvey L., and H. T. Fernald. 1930. Ecological studies of the Mexican bean beetle. Mass. Agr. Expt. Sta. Bul. **26**: 1–32.

Turner, Neely. 1932. Notes on rotenone as an insecticide. JOUR. ECON. ENT. **25**(6): 1228–37.

A HOST PLANT RECORD FOR THE WEEVIL, *Peritelopsis globiventris* (LEC.)

In 1936 the author reported[1] the rather uncommon broad-nosed weevil, *Peritelopsis globiventris* (Lec.) as causing some minor injury to the globe artichoke (*Cynara scolymus*) in Santa Cruz County, California. Since this record it has been found commonly overwintering among and feeding on the nterfolded young leaves of this plant in the same locality. Ting[2] reported a collection of this weevil from the sea side daisy, *crigeron glaucus*, in San Mateo County, California. On June 10, 1940, the author collected several plants (no underground portions) of lizard tail, *Eriophyllum staechadifolium*, from near Sharp Park, San Mateo County, California, to record the emergence of certain Lepidoptera, from which three specimens of this weevil emerged and were removed dead on November 16, 1940. Inasmuch as *Eriophyllum* is a very common perennial composite of the sand dune areas of the coast, and occurs in close proximity to artichoke plantings where damage has been observed, it seems apparent that it is a host of *Peritelopsis*. Numerous collections of *Erigeron glaucus* from the same locality have failed to show the presence of this weevil.—6-18-41.

[1] Pan. Pac. Ent. 12(4): 195.
[2] Pan. Pac. Ent. 13(1–2): 24, 1937.

W. HARRY LANGE, JR.

Timing Cabbage Worm Treatments

G. E. R. Hervey, *New York State Agricultural Experiment Station*

There has been a renewed interest during recent years in the control of the caterpillars attacking cabbage in western New York. This is probably because of the increased abundance of these insects and because it has been demonstrated that an adequate insecticide program on cabbage will give a marked improvement in quality and a substantial increase in yield. The following remarks apply chiefly to the control of cabbage worms on Danish cabbage and on domestic cabbage grown for the manufacture of kraut. The control of these insects on other cruciferous crops, such as cauliflower, broccoli, Brussels sprouts and cabbage on which loose leaves are left at harvest constitutes another problem which is not discussed here.

In this area cabbage seed is usually planted the latter part of April or the first of May and the plants are transplanted in the field during June. Harvesting cabbage for the kraut factory usually starts the latter part of September and often continues well into November. Practically all Danish type cabbage is harvested after November 1.

The two principle pests of cabbage are the imported cabbage worm, *Pieris rapae* L., and the cabbage looper *Autographa brassicae* Riley. The diamond back moth, *Plutella maculipennis* Curtis, and the cabbage aphid, *Brevicoryne brassicae* L., are occasionally troublesome. There are at least three broods of the imported cabbage worm but only two of these are troublesome to the main cabbage crop. The first brood is found on early cabbage. The caterpillars of the second brood commence to attack cabbage about July 15 to 20 and ordinarily they are comparatively few in number. The caterpillars of the third brood, which is the most important one, begin to appear the first week in August and are usually very active throughout most of that month. Very often insect parasites and disease become abundant and greatly aid in reducing the numbers of the insect. The pest is rarely important after September 1. There are also three broods of the cabbage looper in this area, but the insect does not often become abundant before the middle of August. It may, however, continue to be destructive until freezing temperatures occur in the latter part of October.

Under conditions in western New York the major damage caused by the imported cabbage worm is a reduction in yield due to its feeding on the leaves while the plants are still relatively small. The cabbage looper also reduces the yield to some extent, but its principal damage is a reduction in quality caused by the holes or tunnels it produces in the base of the head late in the season.

Most cabbage worm control efforts as practiced by growers in this area have been more or less haphazard, little attention being paid to the timing of treatments or to the number of treatments necessary to give commercial control of the insects. The common procedure has been to delay the application of an insecticide until worm injury is very apparent. The drawback to such a method is that much of the damage has already been done and in many instances the insects have reached a stage of development when they are very difficult to control. The purpose of this paper is to report experiments conducted in 1939 and 1940 designed to give information on which a satisfactory cabbage worm control schedule could be worked out.

Methods.—Both species of worms were considerably less abundant in 1939 than in 1940. There was only a moderate infestation of the imported cabbage worm and very little cabbage looper in 1939. In conjunction with this, growing conditions were rather favorable and as a result the differences between treated and untreated plats were relatively small. In 1940 almost the reverse was true. There was an unusually severe outbreak of the imported cabbage worm which started about July 20 and continued until the first of September. The cabbage looper was also abundant. This insect commenced to appear in the experimental field early in August and it was exceedingly active until the cabbage was harvested in November. Early feeding by the cabbage looper was mostly on the outside leaves, but as the days became cooler during the latter part of September it attacked the head itself. Growing conditions were less favorable in 1940

than in 1939. Subnormal rainfall in August and the first half of September appeared to accentuate the injury of the insects and as a result rather striking differences between plats were obtained.

The treatment used in this experiment was a lead arsenate spray consisting of 10 pounds of lead arsenate and 6 ounces of *Grasselli Spreader-Sticker* to 100 gallons of water. Considerable experience with dusts and sprays for cabbage worm control over several years has proved that this mixture is the most effective treatment for the combined control of both species of worms. Rotenone-bearing dusts have proved very effective against the imported cabbage worm in most cases, but they are much less efficient against the cabbage looper than the lead arsenate spray. On the other hand, certain pyrethrum dusts are very effective against the cabbage looper but less so against the imported cabbage worm. The lead arsenate spray gives a high immediate kill of both species and has a long residual effect. Under conditions in this area it is safe to use an arsenical because the bulk of the cabbage crop is closely trimmed at harvest, thus eliminating the danger of objectionable residues.

The plat arrangement and method used was that described by Glasgow (1940) designed to determine the number of applications necessary in an insect control program and the correct time to apply them. In this case various combinations of treatments up to a maximum of four were used as shown in figures 1 and 2. The dates of spray applications coincided as nearly as possible with the peaks in hatching of the eggs of both species. The spray was applied with a power sprayer and portable two-row boom with three nozzles per row. About 150 gallons of spray at a pressure of 350 pounds were applied per acre. Each plat consisted of two rows which extended across the entire length of the field. There were also three two-row untreated check plats, equally spaced and extending through the experimental plot. The records were taken from four 50-foot strips extending across the plats, thus giving four replicates.

Two methods were followed as a means of determining the value of the treatments. First, the cabbages were weighed and the weights of the treated plats compared with the untreated check plats. This is expressed in terms of percentage increase as shown in figures 1 and 2. Yield records are not entirely satisfactory since certain irregularities caused by variations in soil and variations in insect abundance in different parts of the field are likely to occur unless overcome by careful plat technic. While the difference in yield does

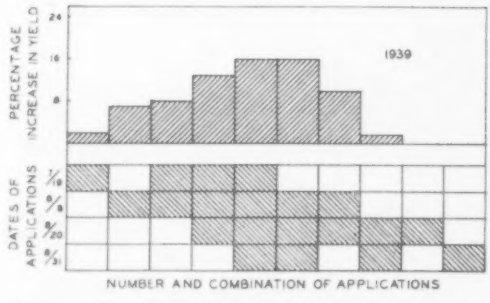


FIG. 1.—The effect of the time of application and the number of applications of lead arsenate spray on the yield of cabbage. Expressed as percentage increase in yield. 1939.

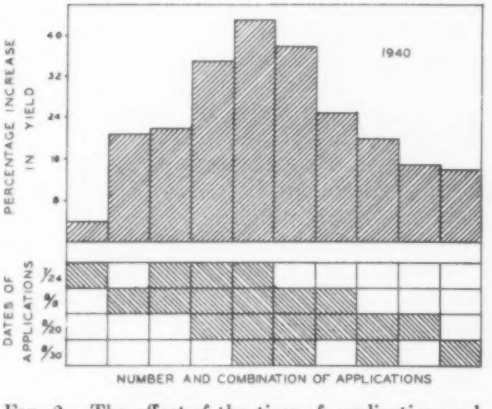


FIG. 2.—The effect of the time of application and the number of applications of lead arsenate spray on the yield of cabbage. Expressed as percentage increase in yield. 1940.

not provide an absolute measure of insect control, such data do have the advantage of being expressed on a numerical basis. The other method used consisted of examining each head of cabbage at harvest to determine the degree of damage, using three categories of classification. While this method has proved useful in estimating cabbage looper injury there is a large error in such data owing to the general nature of the classification, the relatively small number of specimens examined, and the variation in judgment

of the individuals involved in taking the record.

From the purely practical standpoint cabbage growers appear to be most interested in the effect of these insects on the yield. Cabbage heads showing a moderate degree of injury are still entirely saleable and it is only when the crop is severely injured by the cabbage looper that the product may be discriminated against. Therefore, the more important losses would appear to be those affecting the yield of marketable heads.

FIG. 3.—General view of the experimental field. The two rows in the right foreground are untreated.

DISCUSSION OF RESULTS.—The results of the experiment in terms of increased yield are shown in figures 1 and 2. The results of grading the cabbage on the basis of injury for the 1940 experiment is shown in table 1. In considering the figures it will be noted that practically all plats showed some increase in yield regardless of the number of applications or when they were applied. This would seem to be a result of the protection afforded the plant by the treatment. In general, the yield tends to increase as the number of applications are increased. The increases in 1940 were much greater than in 1939 and this is undoubtedly on account of the differences in insect abundance already noted above. This is especially true of the plats receiving only the third or fourth application in 1939 which did not show any increase at all and can be explained by the lack of cabbage looper that season. In considering the plats receiving only single applications it will be noted that the first application seems to be the least effective. This is to be expected since the plants were relatively small at this period and the insects rather few in number. The second application was the most effective single treatment. It is applied at a time when it is very useful against the imported cabbage worm and also has some value against the cabbage looper. The second and third applications seem to be the best combination when two treatments are applied and give fair control of both insects. The differences between three and four applications in 1940 were noticeable, although in 1939 there was little or no evidence that a fourth application was necessary. It is thought that this would be the case in most instances unless there should be an unusually severe outbreak of the insects such as occurred in 1940. There was some evidence in both seasons that where three applications were used, better control was secured when the treatments were started in August rather than in July. This is undoubtedly trye, but there is a practical objection involved in spraying as late as September 1. The plants have usually reached a stage of growth at this time which makes it difficult to get through the field with a sprayer without doing considerable damage.

The results as indicated by grading the cabbage at harvest on the basis of injury follow much the same pattern as shown by the yields. There are some inconsistencies which are due to the method of taking the results as already indicated. In considering the single applications, the first and fourth were of little value, the first being too early and the fourth being applied

Table 1.—The effect of the time and number of applications of lead arsenate sprays on the quality of cabbage as determined by grading the heads at harvest, 1940.

NUMBER AND COMBINATION OF APPLICATIONS*	DEGREE OF INJURY		
	Per cent clean	Per cent slight	Per cent severe
1	25.9	44.6	29.5
2	60.9	33.6	5.5
3	56.7	39.4	3.9
4	38.7	41.1	20.2
2-3	75.4	23.8	0.8
3-4	56.6	36.0	7.4
1-2-3	81.6	16.8	1.6
2-3-4	86.7	12.5	0.8
1-2-3-4	77.3	21.0	1.7
Check (untreated)	18.8	42.6	38.6

* Dates of applications: 1st, July 24; 2nd, August 8; 3rd, August 20; 4th, August 30.

after the insects had become too well established. The second and third were about equal in effectiveness. Where two treatments were applied the combination of two and three was more effective than three and four. Little or no difference is noted between three and four applications.

SUMMARY.—In this experiment an attempt has been made to devise a satisfactory lead arsenate spray schedule for cabbage worm control in western New York. The results would indicate that in order to obtain maximum control of the insects at least three applications are necessary and possibly four in years of severe outbreak. A combination of three treatments directed against the third brood of the imported cabbage worm and the cabbage looper during August would appear to be the logical procedure except that the plants are often too large to make spraying practical at the time when the third treatment would be applied. For that reason the most practical combination would appear to be three applications with the first applied against the second brood of the imported cabbage worm between July 15 and 20 and two additional applications at intervals of about two weeks depending on the development of the insects. While an application against the second brood in July does not appear to have much value by itself it does seem to contribute nearly as much as the other applications when used in a schedule. Where a schedule of two applications is being followed, the minimum number which could be expected to return the operator anything on his investment, the second and third would seem to be the most satisfactory combination.

There are some exceptions to these statements. For instance, it is known that cabbage planted late requires fewer applications for adequate control of the insects than that planted at the normal time. It is also known that the relative abundance of the insects from year to year is an important factor in determining the number of applications necessary to control them. —4-12-41.

LITERATURE CITED

Glasgow, Hugh. 1940. A plat arrangement for timing the applications in a control program. JOUR. ECON. ENT. **33**(2): 357–61.

ANOTHER INFESTATION OF A SCHOOL BUILDING BY *Oeciacus vicarius* HORVATH[1]

In a recent issue of the JOURNAL OF ECONOMIC ENTOMOLOGY (Vol. 33, No. 6, p. 949, December, 1940) Mail describes an infestation of the swallow bug *Oeciacus vicarius* Horvath, in a school building in Banff, Alberta. On May 27, 1940, approximately the same time that the Alberta infestation occurred, a report was received by the Montana Agricultural Experiment Station of a similar infestation in a school building at Cut Bank, Montana. Four specimens were submitted from "swarms" which were said to be occurring in the building, and later a larger collection was received. The school had been vacant for the five years previous, and was being temporarily used during the spring of 1940. There were a number of cliff swallow nests beneath the eaves. Some of the school children claimed to have been bitten by the insects.

One specimen from the last shipment remained alive when it was possible to try a feeding experiment. On June 11 an attempt was made to obtain feeding on a human host. After a 15-minute exposure, it refused to bite one individual. When placed on another it wandered about for a short time, then inserted its mouthparts and fed for about four minutes acquiring a rosy hue and a slightly convex curvature of the abdominal tergites. It was given the opportunity to feed daily, but it did not attempt again until the 15th, when it fed for three minutes, moved to another place and fed again for approximately one minute. It is interesting to note that but one of these feedings produced any pain, and that was similar to a light pin prick. There was no after effect of reddening, swelling, or itching.—5-31-41.

H. B. MILLS and D. J. PLETSCH, *Montana Agricultural Experiment Station.*

[1] In cooperation with the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

Codling Moth Emergence-Activity Studies[1,2]

EDWIN GOULD, *West Virginia Agricultural Experiment Station*, and GEO. H. GEISSLER, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.*

It is generally recognized that during the past ten years or more there has been a progressive increase in the codling moth population in the orchards of the Shenandoah-Cumberland fruit belt. While this increase is quite obvious there are no available accurate records pertaining to the extent of this increase or indicating the principal contributing factors. With these facts in mind a project was outlined and begun in the spring of 1937 for the purpose of determining the fluctuation in codling moth population over a long period of time and correlating weather conditions and other influencing factors with

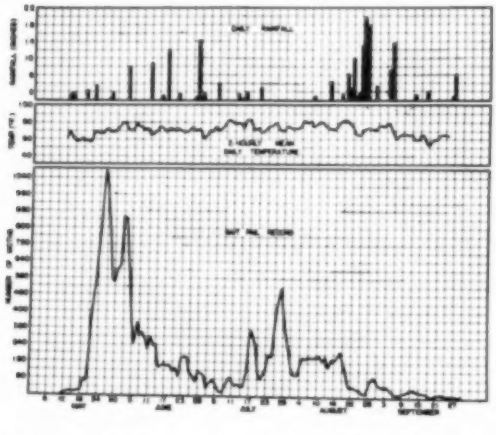


FIG. 1.—Codling moth activity, 1937. Bait pail record graph computed on a 3-day moving average basis.

the fluctuations of population. Results secured are also of value in timing commercial spray applications.

METHOD.—The emergence-activity records were secured by means of bait pails. These records were supplemented with hibernation-emergence and hatch-entry records. The latter were taken in the Cushwa orchard near Martinsburg, W. Va., in connection with a biological-mechanical codling moth control project. The hibernation-emergence studies were made for the purpose of studying the behavior of the codling moth in relation to time of hibernation correlated with emergence and also to determine the duration of the hibernation period. For these studies systematic collections of larvae were made at intervals of 7 to 10 days in such a manner that no lot included larvae which had reached maturity (full growth) more than ten days prior to time of collection. The larvae were placed in cages and dates of emergence of moths were recorded. The results were used to verify the bait pail records. Hatch-entry records were taken in the same orchard as a further check on moth activity. These records were made by frequent examination of marked fruits. Ten fruits were selected from each of ten trees distributed throughout the orchard. These fruits were examined at three-day intervals throughout the period of moth activity. When a fruit was lost an uninjured one in the same locality was selected to replace it.

Emergence-activity was determined by means of bait pails distributed over an 80-mile circuit through Jefferson and Berkeley counties. Thirty pails were used in each county placed in 23 carefully selected well distributed orchards in which the trees ranged from 15 to 30 years in age. They represented varying degrees of infestation from very light to extremely heavy. In general the orchards in Jefferson County were lightly infested

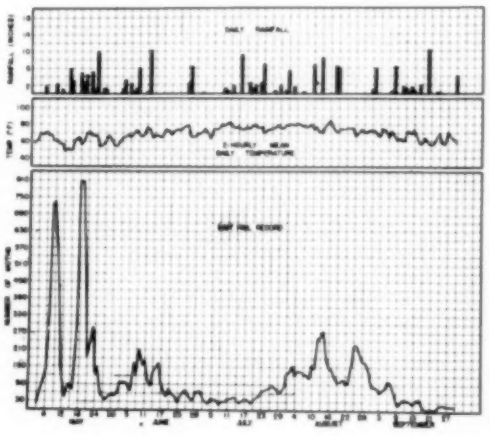


FIG. 2.—Codling moth activity, 1938.

[1] West Virginia Agricultural Experiment Station and U. S. Dept. of Agr., Bureau of Entomology and Plant Quarantine, cooperative project, Kearneysville, W. Va.

[2] Published with the approval of the Director of the W. Va. Agr. Expt. Station as Scientific Paper No. 270.

while those in Berkeley County were heavily infested. The pails were located in the same places each season and were visited daily.

The bait pails were common four quart stew pans. They were filled about half full of bait which consisted of a 10 per cent fermented syrup solution to which had been added 0.2 per cent sodium benzoate. *Blue Label Brer Rabbit* brand syrup was used. It was allowed to ferment for about ten days before being used.

The project was conducted as outlined during 1937 and 1938 but was greatly curtailed during 1939 when only 21 pails were operated. A fairly general selection of Jefferson and Berkeley counties was covered and pails were placed in orchards typical of the region.

RESULTS.—A summary of the results obtained during the three seasons is given in the following discussion. Figures 1, 2 and 4 give a seasonal comparison of daily emergence-activity, temperature and rainfall for the three seasons.

EMERGENCE RECORDS FOR 1937.—The first moth activity in 1937 was noted May 12 with the first peak coming May 26. A second peak of first brood activity was noted June 2. The activity was very great between May 22 and June 4, approximately 85 per cent of the overwintering brood was trapped during this 12-day period. The peak of second brood activity was recorded July 28 but was much lighter than anticipated. A total of only 512 moths was removed from the 60 pails on that date; less than half the number taken during the first brood peak. Third brood activity in the trapped area was negligible.

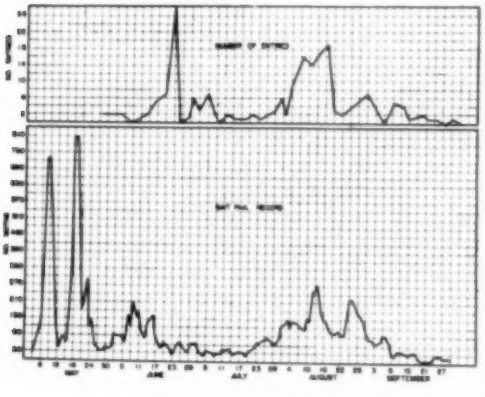


FIG. 3.—Relation of moth activity to times of entry, 1938.

A total of 24,384 moths was trapped in the 60 pails during the season, an average of 400.6 moths per pail. This average might have been considerably greater except for losses due to high winds and heavy rains. The maximum number caught in any one pail during the season was 2,301 while the minimum was 16. The greatest number caught in one pail in one day was 152 while the greatest number caught in one day in the 60 pails was 1,348 or an average of 22.5 per pail. The

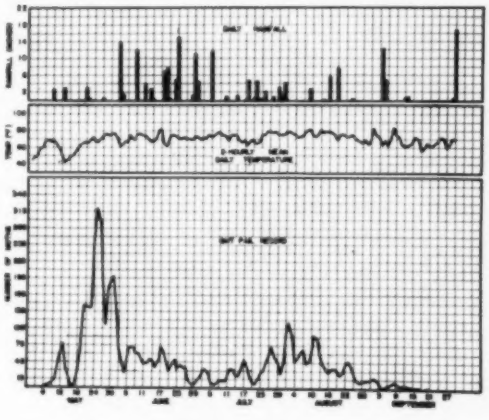


FIG. 4.—Codling moth activity, 1939.

30 pails in Jefferson County caught 9,184 moths during the season while those in Berkeley County caught a total of 15,200.

EMERGENCE RECORDS FOR 1938.—The first brood emergence in 1938 was earlier than normal and very heavy. Due to unfavorable weather conditions second brood emergence was much lighter than expected. The first emergence-activity was noted May 3. There were two definite peaks of first brood activity again in 1938. The first peak was noted May 8 with a total catch of 1,401 moths in the 60 pails. The second peak was May 18 with a total catch of 1,530 moths. A total of 16,895 moths was collected in the 60 pails during the season. This gives an average of 218.6 moths per pail compared with 400.6 per pail in 1937. A total of 9,690 moths was trapped during May and June and 7,205 during July, August and September. This compares with 15,137 and 9,247 during the respective periods in 1937. The maximum daily catch in the 60 pails was 1,530 as compared with 1,348 in 1937. These results would indicate a decrease in codling moth population and a light carry-

over for 1939. Unfortunately these records do not show the prolificacy or mortality of a given population. Band records from the biological-mechanical control project in-

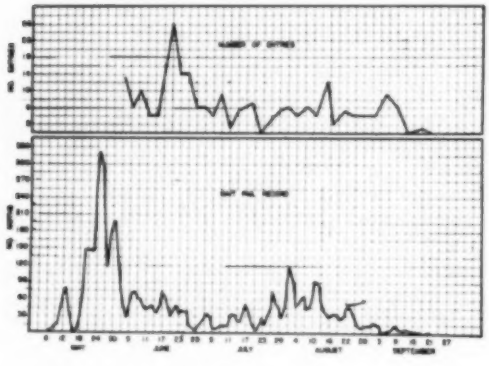


FIG. 5.—Relation of moth activity to time of entry, 1939.

dicated a 1938 carry-over comparable to that of 1937. The records, however, did indicate that the 1938 infestation was much lighter than that of the previous season.

Approximately 67 per cent of the first brood moths were active during the 20 day period of May 3 to 23. Hot dry weather during March and April caused

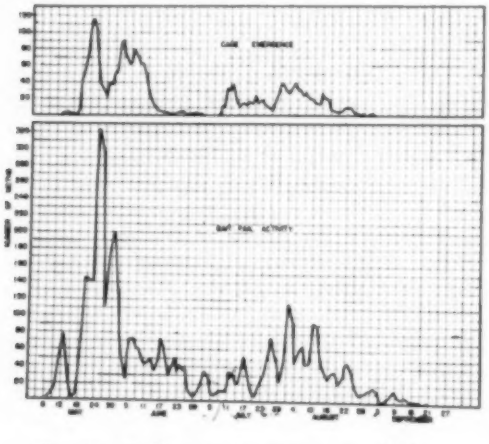


FIG. 6.—Codling moth emergence-activity, 1939 (3-day average).

heavy early emergence-activity but cool weather during May and June resulted in heavy mortality and light infestation. There was practically 100 per cent natural mortality of moths from the heavy emergence-activity which occurred between May 3 and 19.

The hatch-entry records shown in figure 3 indicate that there was very heavy natural mortality of all moths which emerged before the first of June. Since the bulk of the overwintering brood emerged during May, it is quite obvious why first brood was so easily controlled in 1938. Had all early sprays been omitted, the infestation would still have been comparatively light. In the biological-mechanical control orchard, where spraying was discontinued with the petal-fall application, the first brood infestation was only 18 per cent as compared with 38 per cent the following year. The comparatively

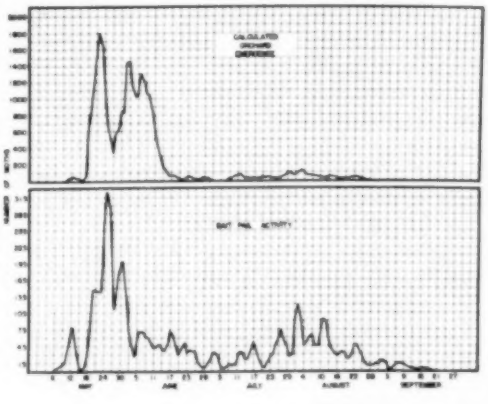


FIG. 7.—Comparison of bait-pail activity and calculated orchard emergence, 1939.

light emergence-activity between June 1 and 19 gave the heaviest infestation of the first brood. Although second brood emergence was comparatively light it produced a much heavier infestation than did the first brood. This also explains the heavy carry-over shown by band collection records.

EMERGENCE RECORDS FOR 1939.—The 1939 records are based on 21 bait pails instead of 60 as for the two previous seasons. In 1939 the first emergence-activity was noted May 7; this increased rapidly until May 12 when it was checked by a period of cold rainy weather. The peak of first brood activity was reached May 24 and continued heavy until June 2. From that date it gradually became lighter until July 1 when practically no flight was in evidence. Adverse weather conditions during late May and June did not materially affect second brood build-up but it did affect first brood control.

The peak of first brood activity oc-

curred May 25 yet the peak of entries did not occur until June 20 (Fig. 5). The much smaller peak of first brood activity noted June 1 was apparently responsible for the peak of hatch-entries noted June 20. However, there may have been some moth carry-over from the first heavy peak of activity. This delayed hatch-entry was clearly evident during both years for which entry records are available. The early moth activity failed to produce early heavy infestation.

The second brood moth activity began about July 10. Two distinct peaks were noted, the first on August 1 and the second on August 10. Activity continued fairly heavy until about August 23. There was a long period of hot dry weather through July and August which favored codling moth build-up. As a result there was comparatively heavy oviposition and low mortality which accounted for the heavy carry-over of 1939 larvae to 1940.

The 1939 cage emergence records are given in figure 6 in comparison with the bait-pail activity records. The close correlation between cage emergence and bait-pail activity tends to verify the accuracy of the bait-pail method for determining codling moth emergence and activity. The 1939 records are representative for the three years for which results are available.

Figure 7 gives the calculated orchard emergence records compared with the bait-pail activity records. The calculated orchard emergence records are based on orchard population and actual cage emergence. Weekly population records are determined from band records from the biological-mechanical control orchard. Bands were removed at weekly intervals from 60 trees and larvae contained were counted. This gave the larval population which matured each week. Samples of 200 larvae were taken from each such weekly collection and placed in emergence cages. Subsequent emergence records from each cage, or weekly collection, were used to calculate the daily emergence from the comparable weekly orchard populations. The emergence from each separate weekly collection was used only for calculating the daily orchard emergence for those larvae which matured during the same period as those used in the cage samples. The calculated daily emergences for each weekly lot were totaled to give the daily orchard emergence. The results show a close correlation between the calculated orchard emergence and the bait pail activity records. They agree even more closely with the bait-pail records than do the cage emergence records.

CONCLUSIONS.—The development of the codling moth is materially affected by weather conditions. The seasonal fluctuation in moth population is determined almost entirely by weather conditions. Dense moth populations may produce only light infestations under adverse weather conditions such as frequently occur during first brood activity.

There is a close correlation between cage emergence and bait-pail activity. This tends to verify the accuracy of the bait-pail method for determining moth emergence and activity. Calculated emergence, based on cage emergence and population of larvae of comparable age, compares even more closely with the bait records. This further substantiates the reliability of bait-pail records in accurately determining moth activity under field conditions.

There was a delayed hatch-entry of first brood larvae clearly evident during both years for which entry records were available. The early heavy moth activity failed to produce corresponding early heavy infestation. Normally numerous first brood entries are noted late in June and July long after all moth activity has ceased for the season.—6-4-40.

Control of the Cotton Aphid and the Boll Weevil in 1940

R. L. McGarr,[1] *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*[2]

In many parts of the Cotton Belt the increase in the cotton aphid, *Aphis gossypii* Glov., following dusting with calcium arsenate for control of the boll weevil, *Anthonomus grandis* Boh., is a serious problem. During the season of 1940 tests were conducted at State College, Miss., to determine the effect on the boll weevil and the aphid of calcium arsenate, micronized calcium arsenate, and calcium arsenate-sulfur mixtures, with and without the addition of derris, nicotine sulfate, or tobacco dust as aphicides.

Plot Arrangements and Treatments.—Four series of field-plot tests were conducted with a total of 146 plots. Each plot was one-twentieth acre in size and contained 10 rows. The plots in each series were arranged in randomized blocks, each block containing a plot of each treatment. Series 1 consisted of 4 blocks with 5 treatments; series 2, 6 blocks with 5 treatments; series 3, 6 blocks with 6 treatments; and series 4, 12 blocks with 5 treatments. The plots were located on the same farm and in cotton planted between April 25 and May 5. Approximately 300 pounds of commercial fertilizer was applied per acre at the time the cotton was planted.

The treatments used in the different series are shown in table 1. Chemical analyses of the insecticides were made in the Division of Insecticide Investigations, of the Bureau of Entomology and Plant Quarantine. The calcium arsenate used was of a commercial brand containing approximately 6 per cent of water-soluble arsenic pentoxide by the New York method and 41.7 per cent of total arsenic pentoxide. The sulfur was that known to the trade as 325-mesh conditioned dusting sulfur. On the basis of the manufacturer's analysis of the derris, the derris mixtures were prepared to contain 0.50 per cent of rotenone, but analysis of the mixtures showed that those in series 2, 3, and 4 contained 0.35 to 0.57 per cent of rotenone as indicated in table 1.

The effect of micronization in reducing the particle size of calcium arsenate-derris mixtures in series 2 was not sufficient to be significant. The mean surface diameter of particles by air permeation showed no correlation with the grinding, or else the difference in particle size brought about by grinding was within the error of the size determinations. The micronized calcium arsenate-tobacco dust mixture in series 3 was prepared from calcium arsenate and scrap tobacco to which trisodium phosphate was added as a conditioner and abrasive to facilitate grinding. The finished mixture contained 0.15 per cent of nicotine. The other combinations of calcium arsenate and nicotine were prepared by adding 40 per cent nicotine sulfate to the calcium arsenate.

Eight effective applications of each insecticide were made in series 1 and six effective applications were made in the other three series. Applications that were washed off by rain within 24 hours were not considered effective. Two applications were washed off in each of series 2 and 3, and 4 applications in series 4. A large number of effective applications were made to determine the control each treatment would give with a high aphid population. The applications were made at about 5-day intervals regardless of the boll weevil infestation, since the tests were primarily for the control of the aphids. Single-nozzle rotary hand dust guns were used for applying the insecticides. The applications were made between July 19 and September 2, early in the morning when the cotton was usually damp or wet with dew and the air was for the most part calm. Approximately 6 pounds of calcium arsenate with and without the aphicides was applied per acre per application and about double this dosage of the calcium arsenate-sulfur mixtures.

Records.—Infestation records for the aphids and the boll weevil were begun on the day of the first insecticide application or the day preceding and were continued at about weekly intervals until all applications had been completed. The aphid infestation records were obtained by counting the aphids per square inch on 100 square inches of leaf area per plot at each inspection. The fourth leaf from the top of the plant was used for making the counts. The infestation records for the

[1] A. W. Faulk, W. R. Smith, and C. A. Wilson assisted in making the field-plot records and R. C. Gaines made the statistical analyses.

[2] In cooperation with the Mississippi Agricultural Experiment Station and the Mississippi State Plant Board.

boll weevil were made by examining for feeding and egg punctures 100 squares per plot at each inspection, except in series 1, where 200 squares were examined. The records for both insects were made on the four middle rows of each plot. From 5 to 7 aphid infestation counts were made and from 4 to 6 boll weevil counts.

No yield records were made in any of the tests this season owing to the lack of uniformity of the cotton. Most of the unevenness of the cotton was caused by the excessive rains early season.

A summary of the insecticides used, the poundage per acre, and the infestation records is shown in table 1.

Table 1.—Results of tests with calcium arsenate and calcium arsenate-sulfur mixtures, with and without aphicides, for the control of the boll weevil and the cotton aphid, State College, Miss., 1940.

Treatment	Dosage per Acre per Application, Pounds	Number of Aphids per Square Inch of Leaf		Average Seasonal Boll Weevil Infestation, Per Cent
		Maximum	Average	
Series 1, average of 4 plots				
Calcium arsenate	6.3	37.03	11.39	2.2
Calcium arsenate plus:				
Derris 90-10 (0.5% rotenone)	6.4	12.95	3.66	4.6
Sulfur 50 50	12.0	28.18	8.72	3.0
Sulfur and derris 45-45-10 (0.5% rotenone)	11.8	4.09	1.05	4.1
Check, untreated		6.96	1.85	9.0
Minimum significant difference:				
5% level			1.86	2.5
1% level			2.61	3.5
Series 2, average of 6 plots				
Micronized calcium arsenate plus:				
Derris 90-10 (0.56% rotenone)	5.8	2.57	.71	3.4
Micronized derris 90-10 (0.57% rotenone)	6.1	3.21	.85	3.7
Calcium arsenate	6.0	25.52	6.20	2.7
Caclium arsenate and derris 90-10 (0.41% rotenone)	6.2	3.29	.90	3.0
Check, untreated		4.41	1.17	7.9
Minimum significant difference:				
5% level			.68	2.2
1% level			.92	3.1
Series 3, average of 6 plots				
Calcium arsenate	5.8	25.88	9.28	5.4
Calcium arsenate plus:				
Nicotine 0.5%	5.8	25.52	6.52	4.6
Nicotine 1.0%	6.0	19.58	4.72	4.8
Derris 90-10 (0.41% rotenone)	6.1	4.56	1.19	4.5
Micronized calcium arsenate, tobacco dust, and conditioner 48 48 4 (0.15% nicotine)	6.0	26.39	7.38	9.1
Check, untreated		9.97	2.43	14.0
Minimum significant difference:				
5% level			1.07	4.8
1% level			1.45	6.5
Series 4, average of 12 plots				
Calcium arsenate	6.1	22.67	7.67	5.4
Calcium arsenate plus:				
Derris 90-10 (0.41% rotenone)	6.2	2.98	.91	6.1
Sulfur and derris 30-60-10 (0.35% rotenone)	12.0	.45	.17	8.1
Sulfur and derris 45-45-10 (0.38% rotenone)	11.6	.92	.29	6.9
Check, untreated		2.27	.71	22.8
Minimum significant difference:				
5% level			.52	4.6
1% level			.69	6.1
Average for all series, 28 plots				
Calcium arsenate	6.0	26.02	8.40	4.2
Calcium arsenate and derris 90-10	6.2	4.81	1.49	4.7
Check, untreated		5.05	1.37	14.9

DISCUSSION.—As shown in table 1, dusting with calcium arsenate or mixtures of calcium arsenate and sulfur for boll weevil control caused significant increases in the cotton aphid populations. In all series the addition of derris to calcium arsenate and to the calcium arsenate-sulfur mixtures when used throughout the season was effective in preventing the aphid infestation from building up. In series 1, however, the aphid control from the calcium arsenate-derris mixture was not so good as in the other series. This was probably because the applications were not quite heavy enough to take care of the influx of aphids from severely infested cotton adjacent to the plots. The calcium arsenate-derris mixture was less effective against the aphid than the calcium arsenate-sulfur-derris mixture, the results being slightly better for the 30-60-10 combination than for the 45-45-10 combination. These results were to be expected, however, since the mixtures containing sulfur were applied at approximately double the rate of the calcium arsenate-derris and therefore contained nearly twice as much rotenone. Also, the sulfur itself apparently aided somewhat in holding down the aphid populations. Mixtures of micronized calcium arsenate and derris, micronized calcium arsenate plus micronized derris, and calcium arsenate plus derris all gave good control of the aphids.

The 0.5 per cent nicotine added to the calcium arsenate and the tobacco dust micronized with the calcium arsenate were not effective in keeping the aphids from building up. The 1 per cent nicotine added to the calcium arsenate considerably delayed the development of the aphid population but was only partly effective in controlling the aphids.

The boll weevil infestation was not of much importance in most of the tests until late in the season, although it was higher in series 4 than in any of the other three series of tests. In series 4 the mixtures of calcium arsenate-derris and the mixtures of calcium arsenate-sulfur-derris gave good control of the boll weevil. There were no significant differences in the boll weevil control from these three treatments and the undiluted calcium arsenate.

SUMMARY.—In tests conducted at State College, Miss., in 1940 calcium arsenate and mixtures of calcium arsenate and sulfur for boll weevil control caused significant increases in cotton aphid populations. The addition of derris to these materials effectively controlled the aphids and held the populations at nearly the same level as the checks. There was practically no difference in aphid control from derris when mixed with regular calcium arsenate, derris mixed with micronized calcium arsenate, and derris and calcium arsenate mixed and then micronized. Nicotine and tobacco dust when added to calcium arsenate were not effective in preventing an increase of aphids.

Calcium arsenate and calcium arsenate-sulfur mixtures with derris gave good control of the boll weevil. There was no significant difference between these treatments and undiluted calcium arsenate under the conditions of this experiment, where the weevil infestation was light.—3-5-41.

FOURTH EDITION OF *Entoma*

Entoma. A Directory of Insect Pest Control. Edited by C. C. Hamilton. Fourth Edition. 197 pages. 1941. Published by the Eastern Branch of the American Association of Economic Entomologists.

If you haven't received your copy of ENTOMA, it is probably because you have neglected to open your second class mail. Be sure you have on your desk the biggest and best ENTOMA yet produced by C. C. Hamilton and his able associates. If you are not a member of the Association (if not, why not?), send Dr. Hamilton, N. J. Agr. Exp. Sta., New Brunswick, one dollar for your copy.—F.L.C.

SCIENTIFIC NOTES

"Poison" or "Insecticide" in Economic Entomology

S. Marcovitch, *Tennessee Agricultural Experiment Station, Knoxville*

Until some 25 years ago the chemical knowledge of an economic entomologist consisted chiefly of the arsenicals, such as paris green and lead arsenate, and nicotine sulphate. The arsenicals were known as "stomach poisons" for the control of chewing insects, whereas nicotine was recommended as a contact poison to control insects of the sucking type.

A considerable development in the use of chemicals for the protection of plants has taken place. A wide variety of insecticides are now employed, some of which are distinctly non-poisonous. The insecticide trade must know how to label its insecticides for the protection of the public.

Insecticides, like antiseptics, are chemicals, but it is interesting to note that the physician prescribes antiseptics or drugs while the economic entomologist thinks and publishes in terms of poisons.

That there exists much confusion in literature in regard to the terminology of "poison" and "insecticide" is evident. This situation has developed without the entomologist being fully aware of the consequences. A perusal of the literature will reveal many illustrations, a few of which were picked at random.

First of all, let us examine the textbooks. In a widely used text there is a chapter on "Contact Poisons." Under this heading there are discussions of such insecticides as nicotine sulphate, pyrethrum, sulfur, lubricating oils, soaps, and derris.

In another textbook we find in the portion dealing with "Insect Control" this statement: "Discussion of insecticides commonly group them, for this reason, as "Stomach Poisons" and "Contact Poisons." Under the former are discussed the arsenicals, fluorine compounds, phenothiazine, rotenone, and nicotine.

A writer in the Journal of Economic Entomology refers to copper arsenate in one sentence as an insecticide and in the next sentence as "the poison."

In an excellent and notable contribution to our sciences one of our prominent entomologists begins his review by a conspicuous heading entitled "Stomach Poisons," and then proceeds to discuss arsenical compounds, cryolite, rotenone and other insecticides. The next prominent heading is "Contact Poisons" under which are discussed sulfur, alcohols, petroleum oil sprays and others. His fourth heading, "Insecticides of Plant Origin," is a much better one.

In a Farmers' Bulletin, under the heading of "Insecticides," a paragraph is devoted to the "Stomach Poisons, such as calcium arsenate, cryolite and paris green" and "Contact Poisons, such as pyrethrum, soap, and nicotine sulphate."

In an extension bulletin from an eastern state occurs the following: "The stomach poisons include lead arsenate, calcium arsenate, paris green, cryolite, and the fluosilicates. The contact poisons are nicotine, pyrethrum, and derris."

In a Farmers' Bulletin on disinfecting seeds there is a heading "Mercury Compounds" under which it is stated: "The chemical corrodes metals; therefore nonmetalic containers made of wood, glass or enamelware should be used." In an entomological textbook this same subject of containers is referred to as follows: "This poison should be mixed in glass or wooden vessels."

These citations illustrate the hold the word "poison" has acquired in the literature.

Definitions of Poison.—If we are going to shake ourselves loose from that word "poison" we should at least know the definition for the word. The New York state law on pharmacy terms any chemical a poison that is liable to be destructive to adult human life in quantities of 60 grains (4 grams). According to this definition, the soluble arsenicals and fluorides such as sodium fluoride and sodium fluosilicate should be classed as poisons because they have been known to cause death in quantities of approximately 4 grams. There will always be people who through carelessness or accident will swallow roach or rat poison. To prevent such accidents a "poison" label should be placed on these two fluorides.

Sollman, in his Manual of Pharmacology, gives this definition: "A poison is any substance which by its ordinary action is capable of destroying life or of seriously endangering health when it is applied to the body externally or in moderate doses (to 50 grams) internally." Even under this broad definition many insecticides such as pyrethrum, soap or cryolite can not be classed as a "poison." Animals fed cryolite in single doses equivalent to 1½ pounds for a human being did not succumb. This compound even though in use for a long time is not even mentioned in books on pharmacology or toxicology. No fatalities from cryolite have ever been recorded in the literature. Cryolite (Na_3AlF_6) contains aluminum which has been found to act as an antidote to fluorine poisoning. In our laboratories we have been able to save animals from a lethal dose of sodium fluoride by incorporating aluminum sulfate. This combination forms cryolite. We have discovered that the very soluble sodium fluoborate with 70 per cent soluble fluorine is entirely non-toxic to rats and insects. It appears that both boron and aluminum form complexes which tie up the fluorine and render them non-poisonous.

It is very evident that the various fluorides differ greatly in solubility and the European laws recognize these differences by holding that sodium fluoride and sodium fluosilicate are poisons whereas cryolite is classified as non-poisonous. When acute toxicities are compared cryolite is found to be much safer than caffeine, the alkaloid of coffee, or than common drugs such as aspirin, acetanilid, and quinine. The minimum lethal dose per kilogram of these materials is as follows: Caffeine, 360 mg., salicylic acid, 300 mg., acetanilid, 700 mg., and quinine, 200 mg. Sodium fluoride has an M.L.D. of 200 mg. per kilo. Many fatalities have been reported with these drugs, yet they are sold in all drugstores without poison labels. Many drugs are now sold with caution labels warning against exceeding the recommended dosage. A caution label appears to be all that is necessary for cryolite. Such a label might read "The contents of this package are to be used for insecticidal purposes and not to be taken internally."

Since some foods such as sprayed apples may contain meager amounts of fluorine, there arose a fear that mottled enamel might become widespread. Since 1932 and until recently, the toxicity of fluorine was emphasized with little regard for the possible useful qualities of fluorine in nutrition. During the past two years a considerable amount of

literature has appeared showing that fluorine may have most important tooth-preservative properties.

As is well known, teeth are higher in fluorine content than other parts of the body. Armstrong and Brekhus (1) analyzed sound and carious teeth and found the fluorine content of the former to be 111 parts per million, as compared with 69 for the latter. Dean (2) made a study of dental caries in Galesburg, Illinois, a mottled-enamel area, and in Quincy, Illinois, a nearby section without mottled enamel. The children of Galesburg showed a reduced incidence of caries.

CONCLUSION.—In Entomological literature one can easily find sulfur, pyrethrum, cryolite, lubricating oils, soaps, and other innocents referred to as "poisons." As a result spray residues have already had more than their share of apprehension by the public.

In order to prevent misunderstanding, it would be well to substitute the word "insecticide" for "poison," and to talk and write about controlling insects and applying remedies or treatments or baits rather than killing and poisoning them.

It is evident that there is room for improvement in the terminology employed on the subject of insecticides. Perhaps this matter should receive special attention by a committee acting for the organization of economic entomologists—5-12-41.

LITERATURE CITED

Armstrong, W. D., and P. J. Brekhus. 1938. Possible relationship between fluorine content of enamel and resistance to dental caries. Jour. Dental Res. **17**: 393.

Dean, H. Trendley. 1940. Fluorine, mottled enamel, and dental caries. Jour. of Pediatrics **16**(6): 782–94.

Color Preference of the Pea Aphid in Western Oregon

C. E. CODY,[1] *Hillsboro, Oregon*

For the past several years in the western Oregon and Washington pea growing areas, field observations have indicated that the pea aphid *Illinoia pisi* (Kaltenbach), has a decided preference for garden pea varieties of dark green color.

This spring an excellent opportunity for checking comparative infestations on different colored varieties occurred when B. E. Maling, Inc. planted in adjacent quarter acre plots 17 varieties of freezing peas.

In classifying the varieties as to color, two classifications were used. Varieties having a distinct light yellow-green color were classed as light; all other varieties from medium green to dark green were placed in the dark class.

Counts were made from 50 six-inch tips selected at random over a comparable distance in each plot. Tips were then placed in a specially designed fumigator devised by the Oregon Agricultural Experiment Station for the purpose of checking aphid infestations on field crops.

After the aphids were released from the tips by the fumigator, they were brought into the laboratory and counted. Counts were made from the following varieties which were blooming and podding out when sampled. Varieties were planted in the order given. Results are shown in table 1.—6-25-41.

[1]Entomologist for B. E. Maling, Inc., Hillsboro, Oregon.

Table 1.—Aphid populations and color class of varieties of garden peas.

VARIETY	COLOR CLASS	AVERAGE APHIDS PER TIP
Asgrow Glacier	light	5.26
Progress 9	dark	17.36
Thomas Laxton	light	5.10
Hundredfold	dark	18.80
Asgrow Teton	light	9.56
Champion	dark	19.76
Multifold	dark	12.32
Morses Market	dark	34.56
72D	dark	21.04
Dwarf Freezer	dark	25.12
M-2286	light	28.80
S-219	light	13.84
No. 83	light	41.76
No. 60	dark	25.12
Alderman	dark	22.84
Improved Alderman	dark	30.72
Stratagem	dark	16.64

Av. light varieties per tip—17.38.
Av. dark varieties per tip—22.20.

California Gull and Insect Control in Utah

GEO. F. KNOWLTON, *Utah Agricultural Experiment Station, Logan*[1]

The California gull, *Larus californicus*, probably is as active today in the control of Mormon cricket and grasshopper outbreaks as it was in the early days when it rendered such notable service to the early Mormon pioneers in 1848. During recent years, serious grasshopper and Mormon cricket outbreaks have again threatened farm crops and rangeland forage. It has not been unusual to find from several hundred to an estimated two to three thousand or more California gulls, circling over the ground, feeding on Mormon crickets in areas where such outbreaks occur, or feeding ravenously upon grasshoppers in a recently-cut alfalfa field. On July 6, 1940, an estimated 4,000 California gulls were feeding upon grasshoppers in a 20-acre field of alfalfa, which had been recently cut and piled, in the Utah Hot Springs area of southern Box Elder County. The birds were a beautiful sight, almost whitening the field. The species which were most abundant were the Packard's, two lined redlegged and lesser migratory grasshoppers (all *Melanoplus* species). Almost equally large numbers of gulls have been observed on various occasions feeding on grasshoppers in the Plain City, Honeyville, Deweyville, and Lakepoint areas, and even aiding substantially in reducing heavy grasshopper outbreaks in Wasatch County in the Charleston-Daniels-Heber area.

On August 19, 1936, at Benson in Cache Valley, an estimated 3,500 California gulls were following a mower, feeding upon grasshoppers which were left exposed as the alfalfa hay was cut. The engorged birds would fly to nearby water in the borrow pit just outside the fence. A similar situation was observed on July 8, and has been observed on various occasions, in this same locality. When excited by

[1] In cooperation with the U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine.

man or other gulls, a number of gulls regurgitated the mass of grasshoppers already eaten. The farmer estimated that the gulls ate more than 90 percent of the grasshoppers from this field. Control on other nearby farms was equally effective.

This one species of bird, alone, must have eaten many millions of these orthopterous pests in the counties of Salt Lake, Davis, Tooele, Weber, Box Elder, Cache, Utah and Wasatch during each of the past several years. In addition the destruction of at least equal numbers of cutworms, white grubs, and other pest insects must be credited to them. Large numbers were observed to feed on army cutworm in 1941 at Heber, Charleston, above Croyden and in Box Elder County. Many mice also were eaten from alfalfa fields which were being irrigated; this has frequently been witnessed with interest and delight by the farmers observing such feeding activity.

The number of California gulls in northern Utah probably has not decreased and may have increased since the early days of the pioneers. However, the cultivated area of northern Utah frequented by this bird has greatly increased. As a result, the average number of seagulls per square mile of cropland seems to have been reduced, giving some farmers the impression that this gull now is less abundant than formerly. It feeds commonly on insects in open fields and in range land where brush is short, and in fields where mowing, plowing or other farm activity is underway.

Thousands of gulls have been feeding upon Mormon crickets in the mountain and canyon breeding areas of this native insect pest, particularly in infested parts of Tooele, Juab and Utah Counties. Benefit from this bird has been especially marked in destroying the remnants of Mormon cricket bands, largely killed out by poison-dust control operations. Such range-land activity has reduced the number of these birds visiting farms. On June 14, 1940, several hundred California gulls were flying over the Tintic Mountain areas of Juab and Utah Counties. Flocks were feeding in many widely scattered canyons and ravines. One gull was collected and twelve mature Mormon crickets counted in its stomach.

Large numbers of gulls have been observed feeding upon Mormon crickets in the Stansbury and Sheep Rock Mountains in Tooele County. Feeding in the foothills near Elberta, Mammoth and Eureka also was observed on various occasions. The California gull undoubtedly is the most appreciated and least molested bird occurring in Utah.—6-30-41.

An Aphid Attacking Pears in the Pacific Northwest[1]

LEROY CHILDS, *Hood River, Oregon*

At various times during recent years, an aphid has been occasionally observed by the writer, feeding on pear trees, particularly the Anjou variety. Associated with this aphis attack has occurred premature ripening of the fruit. Yellowish spots a quarter of an inch or more in breadth, develop upon the surface of the fruit, giving the Anjou pear—normally green in color—a mottled appearance. Normal fruits of this variety are hard and will not ripen under common storage conditions, for several weeks after harvest. In 1939, pears associated with the aphid were found so ripe on the trees, that the thumb could be forced into the tissue upon exerting a limited amount of pressure. Pears of this character mixed with normal fruit at packing time, could cause storage troubles as oftentimes the Anjou is kept in cold storage for four or five months after harvest. The mottled appearance of fruit at harvest time has indicated from past observations that attack perhaps occurs at some state during the development of the fruit.

During June, 1940, this insect was found in several orchards feeding upon the fruits of Anjou. Yellow spotting was found associated with attachment of the aphis. In orchards where the insects were most prevalent, an abnormal premature fruit drop was noticed which continued well into July. Whether or not this condition was associated with the aphis attack, was not determined. It seems quite probable, from the nature of effects on the fruit, that this is the case.

Late in the fall of 1939 a collection of aphids was made from leaves on trees where fruit was present showing the condition above described. The insects were not abundant at the time, but the sooty appearance of the foliage indicated they had been numerous earlier in the season. The aphids were sent to Professor E. O. Essig, who states: "This species is apparently *Macrosiphum macrosiphum* (Wilson), specimens in my collection taken in Glacier National Park, Montana, June 7, 1935, and at Longvale, California, July 3, 1931. I have seen this insect only twice before. One individual I took on the wing in Glacier Park, and the other appears in a collection of aphids which I purchased from Bartholomew some years ago. Apparently its normal host plant is the service berry, and it is quite conceivable that it could also work on pears. Later on if you can send me some winged individuals, I would be most happy to receive them for my aphid collection."

Both winged and wingless insects were sent to Professor Essig from the June, 1940, collection. He writes as follows:

> "I am pleased to have your letter of June 26, and the nice lot of aphids taken on pear trees this summer. (This species is, I think, without doubt *Macrosiphum macrosiphum* (Wilson) which is I think the preliminary determination I gave you last year. This species was described as *Illinoia macrosiphum*, by Wilson in 1912. Taken on *Amelanchier alnifolia* (June berry) Corvallis, Oregon, July 4, 1912 (Can. Ent. 44: 155–6, 1912). Some specimens taken on wild rose under *Amelanchier*. Apparently this is another case of a native insect going over onto a commercial agriculture crop. I think it would be a good thing if you would write a little note concerning this find and send it on to the JOURNAL OF ECONOMIC ENTOMOLOGY. In case the insect does become a regular pest, a record of the first occurrence would be important. Does this aphid cause any distortion of the leaves?
>
> "You might also be interested in knowing that among these specimens was a single winged green peach aphid, *Myzus persicae* (Sulzer), which might have simply been resting on the pear tree."

Recent field observations indicate that it is this insect that is responsible for the development of the so-called "pink end" of Bartlett pears, a disorder that produces premature ripening of the Bartlett. Complete control of the insect was obtained in the spring of 1941 from the use of oil (3%) with a late dormant application of lime sulfur and also nicotine sulphate similarly applied. Tests are underway to experimentally prove the relationship of this aphid to the occurrence of "pink end" of Bartlett.

The writer has observed this aphid attacking Anjou pear in Wenatchee and Yakima valleys of Washington and at Hood River, Oregon.—5-28-41.

[1] Contribution from the Montana Agricultural Experiment Station No. 149.

The Pacific Drain Fly in Homes

ARNOLD MALLIS and R. J. PENCE,
University of California, Los Angeles

In the spring of the year, the ordinary individual observes with astonishment and usually some annoyance the apparently mysterious emergence of a minute moth from the drain of sinks and bathtubs. Closer observation reveals that this is no moth but the Pacific drain fly, *Psychoda pacifica* Kincaid, (Fig. 2).

According to Essig (1926) this insect is distributed throughout the Western United States from southern California to Alaska. The adult is 2–2.3 mm. long with brownish-gray wings. The body and wings are densely covered with long hairs, giving the fly a moth-like appearance, and for this reason members of the family are often referred to as "moth-flies." The wings are borne over the body in a roof-like manner. Each segment of the 13-segmented antenna has a bulbous swelling with a whorl of long hairs.

It is believed that an infestation of this drain fly was encouraged in an ordinary sink drain through the use of copious amounts of soap during ordinary lavation. After some 6 or 7 adults were observed to emerge, the drain was dismantled so that the trap portion could be swung free. A paper swab with an outer coating of wax paper was then rammed down the drain by means of a curved wire. As a result of this, a gelatinous-appearing material that adhered to the inner wall of the drain was deposited in a receptacle. The gelatinous-appearing material was then examined under a binocular microscope, and 5 maggots, 6 cast skins of the maggots, and 1 pupa were found.

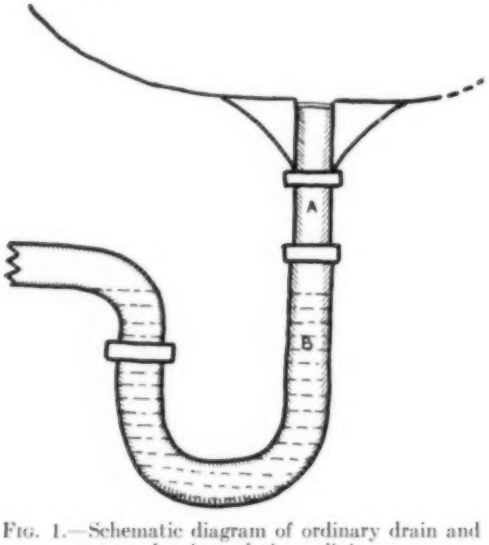


FIG. 1.—Schematic diagram of ordinary drain and trap showing gelatinous lining.

If figure 1 be examined, it will be seen that the drain may be separated into two parts; (B) a permanently water-filled trap, and (A), a water-free entrance to the trap. Each part of the drain is lined with the gelatinous-appearing material, but the lining of the water-free portion is of a much lighter color. The immature insects were found only in this lighter material that occurs in (A) in figure 1. This corresponds with Headlee & Beckwith's (1918) studies on a closely related eastern psychodid, the sprinkling sewage filter fly, *Psychoda alternata* Say. They found this fly to breed in a matrix of organic

FIG. 2.—The Pacific drain fly: larvae and pupa (10×), adult (15×).

gelatinous material in which the larval and pupal stages rest in the film with the breathing tube or tubes projecting through the film into the atmosphere. In the light of these facts we may conclude that the Pacific drain fly exists only in the gelatinous-appearing lining situated above the water-filled trap.

The larvae and pupae, figure 2, when immersed in this gelatinous-appearing material are apparently resistant to hot water and many poisonous and caustic materials. Thus a few of the drain flies were found to emerge from the entomological laboratory sink in U.C.L.A. despite the fact that insecticides, acids, and materials of a like nature were constantly washed or poured down the drain. Turner (1923) speaking of *Psychoda alternata* Say, states, "It is very difficult to drown the larvae as the spiracle may even if pushed below the water, entrap a bubble of air in the hair circle about the opening and carry this down with them. Specimens have been submerged for nearly two days without harm to them, but will eventually drown." In view of the aforementioned facts, we can well understand the persistence of the Pacific drain fly in sink and bathtub drains.

Headlee (1919) notes that the larva of *Psychoda alternata* Say may feed on sediment, decaying vegetation, and microscopic plants and animals in the film. Turner (1925) who studied the genetics of *P. alternata* Say found the adults to lay the eggs on the gelatinous-appearing film. The larva is immersed

in the film with its siphon projecting outside of it. The fly pupates in the film and the pupa has two breathing tubes extending into the atmosphere. Headlee & Beckwith found that the adult lays from 30 to 100 eggs. According to Turner (1923) the life history extends from 8 to 24 days at temperatures of 15° to 30° C. He also notes that the positively phototropic adult on emergence is sexually mature and copulates within a few hours.

Control of the Pacific drain fly was obtained through the use of the previously described method whereby the drain was disconnected and the gelatinous lining was rammed out with a paper swab coated with wax paper. A plumber's probe may be used to force the paper swab through the pipe. In this manner the medium within which the Pacific drain fly breeds is removed. Considerable time must elapse before the gelatinous lining accumulates in sufficient quantity to permit reinfestation.—5-25-41.

LITERATURE CITED

Essig, E. O. 1926. Insects of Western North America.

Headlee, T. J., and C. S. Beckwith. 1918. Sprinkling Sewage Filter Fly, *Psychoda alternata* Say. JOUR. ECON. ENT. **11**: 394–401.

Headlee, T. J. 1919. Practical Application of the Method Recently Discovered for the Control of the Sprinkling Sewage Filter Fly. JOUR. ECON. ENT. **12**: 35–41.

Turner, C. L. 1923. The Psychodidae (Moth-Like Flies) as Subjects for Studies in Breeding and Heredity. Biol. Bull. **57**: 545–58.

Turner, C. L. 1925. A Mutation in the Moth-Like Fly (*Psychoda alternata*) and the method of its transmission. Biol. Bull. **48**: 128–38.

Brachyrinus sulcatus Fab. in Southern California

DAVID B. SCOTT, Jr., *Whittier, California*

In recent months, *Brachyrinus sulcatus* Fab., commonly known as the black vine weevil, has caused considerable concern among Southern California nurserymen. Camellias, azaleas, and occasionally rhododendrons and yews grown in lathhouses apparently are preferred hosts in this locality at this writing.

The injury to camellias and azaleas by the advanced instar larvae is characterized in the majority of cases by partial or complete girdling of the trunk of the plant just beneath the surface of the soil and peat moss growth medium. Plants so attacked may linger for months, suddenly dying in the Fall or Spring because of their inability to transfer sap from the leaves to the roots or vice-versa. Observations so far have shown that camellias up to three years old are readily killed by the larvae. Azaleas are injured and killed for much longer periods, many with trunks more than an inch in diameter having been killed.

The overwintering larvae of *B. sulcatus* begin their pupal stage in mid-April in California. This date may vary according to the duration and severity of the winter months and the degree of exposure to the sun of the plant beds and pots. In Southern California nurseries, records indicate that the peak emergence date of the adult black vine weevils is in May.

The adults then begin their nocturnal feeding on the upper foliage of the plants, leaving characteristic identations along the margins of the leaves. According to Smith (1932), in Pennsylvania, the parthenogenetic preoviposition period following the emergence of the adult weevils may last from four to ten weeks, during which time the weevils feed more freely than at any other time. The length of the preoviposition period in California has not been determined fully as yet, but control measures have been predicated on a basis of five weeks.

Several years ago, in a certain district in Southern California an infestation of the cribrate weevil, *Brachyrinus cribricollis* (Gyll.) threatened nursery stock including species of *Lonicera*, *Umbellularia*, and *Pittosporum*. A long range, intensive program of pest control directed against the adults with sprays of natural cryolite has nearly eradicated the weevil in that area. Inasmuch as fluosilicate baits so commonly used to control the adults of *B. sulcatus* in the Northwest have proved to be more or less ineffective in Southern California nurseries, effective control measures are now being developed which are based upon the experiences with natural cryolite sprays against *B. cribricollis*. It was significant that the kill with the natural cryolite sprays, though complete and efficient, took about 36 hours to accomplish. During the first 24 hours very few beetles succumbed but after that toxicity was great.

Smith (1927, 1932), Essig (1933), and Wilcox *et al.* (1934) give good accounts of this pest.—7-11-41.

LITERATURE CITED

Essig, E. O. 1933. Economic Importance of the Genus *Brachyrinus*. Monthly Bul. Calif. Dept. of Agric. **22**: 7, 8, 9, 10, 11. 397–409. July–Nov.

Smith, Floyd F. 1927. The Black Vine Weevil (*Brachyrinus sulcatus* Fab.) as a pest in Greenhouses and Nurseries. JOUR. ECON. ENT. **20**: 127–131.

Smith, Floyd F. 1932. The Biology and Control of the Black Vine Weevil. U. S. Dept. of Agric. Tech. Bul. **325**.

Wilcox, J., Don C. Mote, and Leroy Childs. 1934. Root Weevils Injurious to Strawberries in Oregon. Oregon Agr. Expt. Sta. Bul. **330**.

Cotton Aphid Multiplication following Treatment with Calcium Arsenate

E. W. DUNNAM AND J. C. CLARK, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Studies of the factors that cause the cotton aphid, *Aphis gossypii* Glov., to increase following the use of calcium arsenate were begun at Stoneville, Miss., in 1938 and the preliminary results were reported at the meetings of the Cotton States Branch of the American Association of Economic Entomologists at Tampa, Florida, in February 1939 and at Birmingham, Alabama, in February 1940. Evidence was presented showing that factors other than the destruction of their parasites and predators were playing a part in the accelerated multiplication of aphids on cotton following dusting with calcium arsenate for boll weevil control. Since practically no parasites were present and the number of predators was in-

significant in 1938, the suggestion was made that the calcium or arsenic in the insecticide was absorbed by the cotton and that one or both of these elements in the leaf fluids upon which the aphids feed might have acted as a stimulus on the rate of reproduction. The records indicated that some of the insecticide was taken up by the leaves and some by the root system. The pH of the soil was increased in the plots of cotton dusted with calcium arsenate and it was believed that the calcium also increased the pH of the leaf cell sap and enhanced its food value for aphids. Associated with this increase in pH was earlier maturity of the plants and shedding of leaves. It was thought that the arsenic stimulated aphid reproduction and caused the shorter prereproductive period, the greater number of young born daily, and the larger total number of young per aphid observed on the dusted plants.

Further work since 1938 has tended to confirm these opinions. The pH of the cotton leaf cell sap has been found consistently higher in plants dusted with calcium arsenate than in the controls. Aphids were found to multiply more rapidly when caged in 66-mesh organdy bags on cotton leaves dusted with calcium arsenate containing 0.7 per cent of water-soluble arsenic pentoxide (New York method) than when similarly caged on untreated leaves. These cages kept out the parasites and predators but did not prevent lodging of the dust on the leaves. Caged aphids reproduced still more rapidly on leaves dusted with calcium arsenate containing 13.9 per cent of water-soluble arsenic pentoxide. On cotton dusted with hydrated lime aphids reproduced slightly faster than on the controls. In field tests at Tallulah, La., Gaines *et al.* (1940) found that a significantly larger number of aphids developed in plots of cotton dusted with calcium arsenate containing a high (10.3) percentage of water-soluble arsenic pentoxide (New York method) than in plots dusted with calcium arsenate containing a low (0.5) percentage.

These facts indicate that whereas the amount of water-soluble arsenic was the most important factor, the hydrated lime in the calcium arsenate also contributed to the aphid increase. Tests were begun in the spring of 1939 to ascertain whether commercial calcium arsenate could be so improved as to reduce or eliminate the build-up of aphids following its use. The objective was to find a material that would act as a buffer for the water-soluble arsenic pentoxide, reduce the alkalinity, and permit the cotton plant to overcome any possible injury caused by the remaining water-soluble arsenic pentoxide.

To observe the reaction of cotton and aphids to various materials, sprays were prepared by mixing each of the following with water: Borax (pH 9.12), ferrous sulfate (pH 2.50), Bordeaux (pH 11.70), zinc sulfate (pH 4.96), magnesium sulfate (pH 7.50), manganese sulfate (pH 2.16), and wettable sulfur (pH 8.62). For the same purpose, plots were dusted with calcium arsenate (pH 11.80), lead arsenate (pH 7.56), zinc arsenate (pH 6.40), magnesium arsenate (pH 9.61), a commercial mixture of paris green reacted with calcium arsenate (pH 11.61), hydrated lime (pH 11.80), wheat flour (pH 5.18), and 325-mesh dusting sulfur (pH 8.40). All sprays and dusts were applied three times during the season of greatest plant activity. Although the aphid population was relatively low in all plots, the cotton plants receiving the zinc arsenate, with a pH of 6.40, had fewer aphids and appeared in better condition at the end of the summer than the plants treated with the other materials. The yield of cotton was also greater in these plots, although the damage by boll weevils was very low and was not a factor in producing a full crop. These results indicated that among the materials that could be used for neutralizing and buffer purposes zinc salts would probably be the most suitable for use with calcium arsenate for cotton insect control. Tests are being continued with mixtures of calcium arsenate and zinc salts and calcium arsenate and ferrous salts in comparison with a commercial brand of calcium arsenate in which a zinc salt was included in the manufacturing process.—7-21-41.

LITERATURE CITED

Gaines, R. C., M. T. Young and G. L. Smith. 1940. Effect of insecticides used in boll weevil control upon aphids and mirids. JOUR. ECON. ENT. **33** (5): 792–6.

Eucordylea huntella Keifer[1] as a Pest of Rhododendron

CHARLES F. DOUCETTE, *U. S. Department of Agriculture, Bureau of Entomology and Plant Quarantine*

Injury to flower buds of native rhododendron, *Rhododendron californicum* Hook., was noted by the writer in Curry County in southwestern Oregon early in 1939. Small pink-tinged lepidopterous larvae were found to have partly girdled the stems at the bases of the buds, after which they had worked upward into the buds, where a considerable portion of the tissue was eaten (Fig. 1). Injured buds collected that season yielded only a few moths, but from a large number of injured buds collected in the spring of 1940 many adults were obtained. These were determined by J. F. Gates Clarke as *Eucordylea huntella* Keifer.

Keifer's original description (1936) is the only reference to this species found in literature. He states that adults were reared from material collected "on the middle fork of the Mokelumne River, the West Point district, Calaveras County," Calif. Keifer reports *Rhododendron occidentale* Gray, the native azalea, as the host, and the flower buds as the part of the plant attacked.

In the coastal area of Oregon the writer has observed injured flower buds of native *Rhododendron californicum* plants in various places between Florence, in Lane County, and the California state line. There seemed to be much more damage in the more southern locations. From 10 to 40 per cent of the flower buds on the various plants examined had been attacked. Native azalea plants were carefully examined both in 1939 and 1940, particularly in Azalea State Park, Brookings, Oregon, but no indications of injury were found. Even though growing contiguous to infested rhododendron plants, azaleas were apparently not attacked.

Larvae removed from infested rhododendron flower buds collected at Brookings in March 1940 varied considerably in size. From buds kept under ordinary room conditions adult emergence began on April 2 and continued until May 17. In this material the larvae pupated within the buds.

Rhododendron plants in the Brookings area were examined on September 19, 1940, and several infested flower buds were found. At this time the only indication of infestation was a slight amount of frass that had been pushed out of the larval burrow at the

[1] Lepidoptera, Gelechiidae.

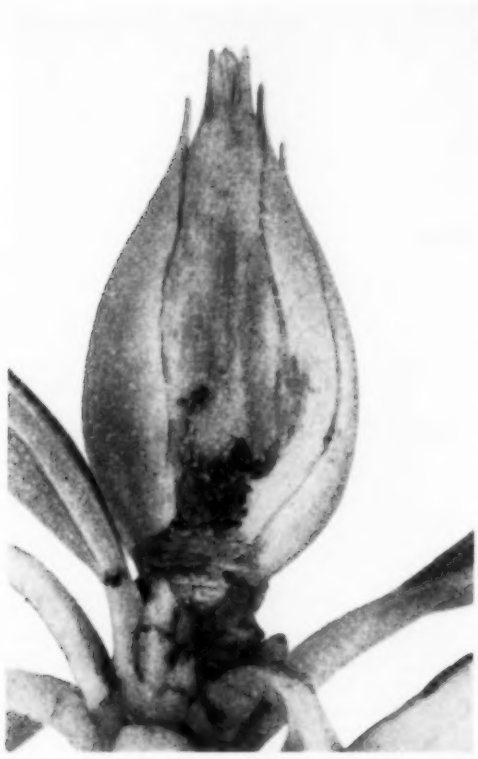


FIG. 1.—Injury to rhododendron flower bud by larva of *Eucordylea huntella*.

base of the bud. The larvae noted in September were all very small. In the early spring the infested buds appear somewhat yellowed and often fail to open as the season progresses.

Parasitization is apparently extensive. *Copidosoma nanellae* Silv. (determined by A. B. Gahan) seemed very abundant both in 1939 and 1940. The adults emerged in May and June. One specimen of a species of *Apanteles* (determined by Gahan) was reared in 1940. One specimen of *Epiurus* sp. (determined by R. A. Cushman) emerged June 22, 1939. Adults of *Eubadizon* sp. (determined by C. F. W. Muesebeck) emerged March 25 and April 1, 1940. A large number of a tachinid, *Lispidea* sp. (determined by D. G. Hall), developed from the Brookings material in March and April 1940.—6-2-41.

LITERATURE CITED

Keifer, H. H. 1936. California Microlepidoptera VIII. South. Calif. Acad. Sci. Bul. **35.**

The Effect of Tillage on Grasshopper Eggs[1]

HARLOW B. MILLS, *Montana Agricultural Experiment Station, Bozeman*

During the autumn of 1938 great swarms of the lesser migratory locust (*Melanoplus mexicanus* Sauss.) migrated into Montana from the south and east. These hoppers concentrated their eggs in one large egg bed involving all or parts of thirteen counties in the northeast and east-central part of the state. The first hatch in the spring of 1939 was noticed on May 5. This hatch was remarkably uniform, as was indicated by nymphal counts made the last weeks in May, when 68.9 per cent were in the second instar, 23.3 per cent in the first, and 7.7 per cent in the third, with over 90 per cent of the eggs hatched. The infestation was almost entirely of the one species, and was extremely intense. These conditions with the uniform hatch, were ideal for a study of the effect of different cultivation methods on the hatching of the eggs.

A total of 112 fields were examined, and nymphal counts made. The type of tillage in the spring was noted for each field. In many cases, however, it was impossible to discover the exact tillage procedure, and for this reason all plowing, either by the disc or moldboard, was grouped under one heading. Idle land, with no treatment, was used as the check. The following (Table 1) are the nymphal counts per square yard according to tillage method:

Table 1.—Populations of nymphs in varied conditions.

TILLAGE METHOD	NO. FIELDS EXAMINED	NYMPHAL POPULATIONS
1 year idle	33	113.3
2 years idle	7	97.7
3 to 5 years idle	5	90.0
All idle	45	108.3
Stubbled-in grain	19	68.7
Single disk	7	73.3
Double disk	15	45.1
All disking	22	54.1
Duck foot	9	29.1
Plow	17	8.1

On the basis of this table the effect of the various soil treatments, with idle untreated land considered as 100%, is as follows (Table 2):

Table 2.—Effect of soil treatment on survival of grasshopper eggs.

TILLAGE PRACTICE	POPULATION PER SQ. YD. LAST WEEK IN MAY, 1939	PER CENT SURVIVAL IDLE LAND = 100%
Plow	8.1	7.5
Duckfoot	29.1	26.8
Disk	54.1	50.0
Stubbled-in	68.7	63.4
Idle	108.3	100.0

From the data here given a number of things are apparent. In the first place, any procedure which will stir up the soil will affect the survival of *M. mexicanus* eggs. There is, however, considerable difference in the percentage of survival with various methods of tillage. Idle land seems to become regularly less attractive to ovipositing lesser migratory hoppers as the years pass. Double disking is considerably better than a single treatment. Plowing is by far the best treatment for the destruction of the eggs in the soil. When the soil contains a sufficient number of eggs to produce a large population of grasshoppers, stubbling-in grain without previous soil treatment is a dangerous practice.—5-31-41.

[1] Contribution from the Montana Agricultural Experiment Station No. 150.

Control Studies of the Woolly Apple Aphid

C. F. SMITH, *Agricultural Experiment Station, Raleigh, N. C.*

The woolly apple aphid, *Eriosoma lanigera* Hausmann, is a very common and destructive pest on the roots of young apple trees in North Carolina. One nursery lost approximately 10,000 trees because of this insect in 1939 and approximately 85 per cent of the 25,000 trees that will be dug in 1940 are infested.

Experimental work on nursery stock during the past two years has indicated that satisfactory control may be obtained with a basic solution of sodium cyanide without injuring the tree. The sodium cyanide was dissolved in water which was slightly alkaline and the solution was then poured around the base of the tree and covered with a little soil.

The acid in the soil (all the soil tested from nurseries in North Carolina had a relatively high hydrogen ion concentration) neutralized the alkali of the solution and released hydrocyanic acid gas which killed the aphids. All the aphids were killed on the roots of approximately 95 per cent of the trees treated when 0.2 to 1 gram of sodium cyanide was used per tree in 1 quart of alkaline water. Injury to the tree occurred when more than 1 gram of sodium cyanide was used per tree or when 1 gram was used in less than 1 quart of water.

Fair control was also obtained with carbon disulphide[1] 1–1600 or dichlorethyl ether, 1–800, when used at the rate of 2 quarts per tree. However, injury was observed on some trees and control was not as uniformly good as with the alkaline solution of sodium cyanide.—6-14-41.

[1] See Underhill, G. W. and James A. Cox. Carbon Disulphide and Dichlorethyl Ether as Soil Fumigants for the Woolly Aphid, *Eriosoma lanigera* Hausmann. Reprint from February issue Virginia Fruit, 1940.

Two Little Known Scale Insects

E. O. ESSIG, *University of California, Berkeley*

During the past year the writer has received specimens of two scale insects which are relatively new to the New World. The first of these is *Lecanium kunænsis* Kuwana, which was collected on apple at Walnut Creek, April 21, 1941, by A. D. Borden. The mature scales are almost globular, rich brown to almost black, covered with fine pulverulence and measure from 3 to 4 mm. in diameter. This species occurred in considerable numbers on the 1-year and 2-year-old wood. Harold Morrison, Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, who determined the species, states that J. G. Sanders referred to this same species as *Physokermes insignicola* (Craw) on cherry at North Temascal, California, September 15, 1896. Kuwana reported it on *Prunus mume*, *P. sinensis*, and *Rhamnus japonica* in the original description in 1907.

The second, *Chionaspis etrusca* Leonardi, was taken on *Tamarix* sp. at Visalia, California, by A. D. Rizzi, June 25, 1941. Morrison, who also identified this species, reports it on this same host from the Imperial Valley, California, and also from Arizona and Texas. This scale was described by Leonardi in 1908 from specimens collected on *Tamarix* sp. in Italy. It was also collected on this host in France and South Algiers by Balachowsky, 1925, 1932, and Céard, 1927, from Ile de Djerba by P. Marchal, 1910, and from Maroc by De Lépiney and Mimeur, 1925–28, and Vayssière, 1930. The insect occurs in sufficient numbers to completely encrust the twigs of the host plant. It appears to limit its feeding wholly to species of *Tamarix*.—7-21-41.

LITERATURE CITED

Balachowsky, A., 1932. Étude biologique des coccides du Bassin Occidental de la Méditerranée. Encyclop. Ent. Lechevalier & Fils, Paris, p. LII.

Cockerell, T. D. A., 1909. Japanese Coccidæ, Can. Ent. **41**: 56.

Kuwana, S. I., 1907. Synoptical List of the Coccidæ of Japan. Bul. Imp. Centr. Agr. Expt. Sta., Japan **1, 2**: 101.

Leonardi, G. 1908. Seconda contribuzione alla conoscenza della Cocciniglie Italiane. Boll. Lab. Zool. Gen. Agr. R. Scuola Sup. Agr. Portici III: 184–816.

Lindinger, L. 1912. Die Schildläuse (Coccidæ) Europas, Nordafrikas und Vorderasiens. Ulmer, Stuttgart, p. 318.

Trichogramma and the Oriental Fruit Moth

C. F. SMITH, *Agricultural Experiment Station, Raleigh, N. C.*

During the summer of 1940 a small experiment was conducted with *Trichogramma minutum* (Georgia strain) as a means of controlling the Oriental fruit moth. A block of 25 trees, 15 Augbertas and 10 Hales, was used for the experiment. Approximately 5,000 *Trichogramma* were liberated on each tree on each of the following dates, June 30, July 2, 8, 13, 23, 30 and August 5, 12. Bait pans were set out and an examination of these traps showed that Oriental fruit moths were present from June 27 (the date the pans were put up) to August 23. Approximately 1,000,000 *Trichogramma* were liberated on the 25 trees at the time the moths were present in the field. All of the Hales were harvested by August 15 and the Augbertas by August 25.

Table 1.—Comparison of the numbers of fruits infested with oriental fruit moth when parasites have been introduced and when parasites have not been introduced. Fifty fruits were examined for each count.

	Parasites Introduced		No Parasites Introduced	
Date	Augberta	Hale	Augberta	Hale
Aug. 5	2	4	5	3
Aug. 14	4	3	0	2
Aug. 20	7	—	3	—

These meager data indicate that *Trichogramma* is of no value in the control of the oriental fruit moth when only a light infestation is present.—5-1-41.